THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Published by the SOCIETY OF AUTOMOTIVE ENGINEERS, INC., *29 W. 39th St., New York*

J. H. HUNT, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

Vol. XXI September, 1927 No. 3

CONTENTS

General Design and Research

Automotive Research 222
Some Mechanical Features of Suspension Leaf-Springs—Tore Franzen, S. P. Hess and Clark A. Tea 231
Six-Cylinder Engines for Trucks—Ethelbert Favary 239
Notes on Valve-Spring Surge—W. T. Donkin and H. H. Clark—(Discussion) 243
Modern Practices in Automobile-Body Designing—A. E. Northup 257
Rubber as a Material for Mechanical Engineering—W. A. Gibbons 262
Relation of Research to Industry—W. S. James 265
Gasoline—Past, Present and Future—A. Ludlow Clayden 277
Head-Lamp Adjusting Mechanisms and Law Enforcement—Walter W. Matthews 289
Engine-Cylinder Lubrication—Lawrence T. Wagner 311
Reciprocating Balance in Engines of Six and Eight Cylinders—M. V. Davidson 315
Standardization Activities 320

Production Engineering

Production Meeting Program 217
Production Engineering 225
Cast Iron in the Automotive Industry—E. J. Lowry—(Discussion) 254
Modern Automobile-Production Methods—W. K. Swigert 286

Operation and Maintenance

Operation and Maintenance 228
Electric Drive as a Motorcoach Transmission—Charles Froesch 268

Aeronautical Engineering

Modern Naval Aircraft—Lieut-Com. Lawrence B. Richardson, U. S. N. 245
Airplanes for Commercial Aviation—A. H. G. Fokker 250

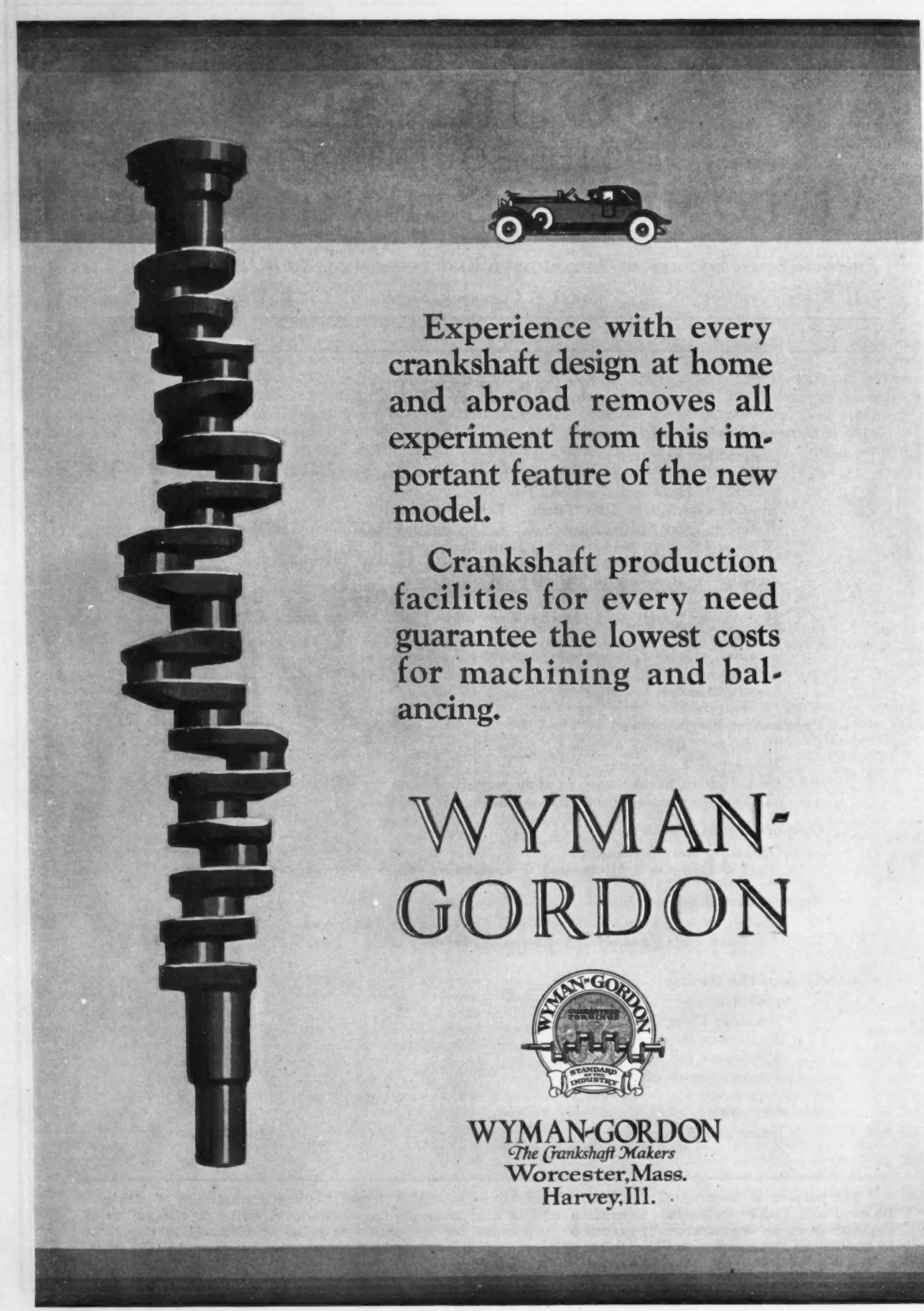
News of the Society

Chronicle and Comment 213
Meetings Calendar 216
Applicants Qualified 327
Applicants for Membership 328
Personal Notes of the Members Adv. Section 20

Miscellaneous

Notes and Reviews Adv. Section 30

The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.


Experience with every crankshaft design at home and abroad removes all experiment from this important feature of the new model.
Crankshaft production facilities for every need guarantee the lowest costs for machining and balancing.
WYMAN-GORDON
WYMAN-GORDON
The Crankshaft Makers
Worcester, Mass.
Harvey, Ill.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XXI September, 1927 No. 3

Chronicle and Comment

The Production Meeting

FINAL plans for the Production Meeting are outlined on p. 217 of this issue. The papers to be presented at the sessions in Cleveland and Detroit will, in the majority of cases, be preprinted and copies will be sent, upon request, to members desiring to study the papers prior to the meeting.

The demand for reservations for the Stag Carnival on Tuesday evening, Sept. 20, indicate that the annual Production Meeting Stag Carnival has become an established major event in Society activities.

September Handbook Issue

THE September, 1927, issue of the S.A.E. HANDBOOK will be mailed to members about Sept. 15, and should be received shortly after arrival of this issue of THE JOURNAL. The new volume, embodying new features, includes 7 new specifications and 12 revisions of existing specifications. Two cancelled standards have been eliminated. A list of subjects covering these changes will be found in Standardization Activities in this issue of THE JOURNAL.

Members who do not receive their copies of the September issue of the S.A.E. HANDBOOK should inform the Standards Department immediately, so that shipment may be traced.

The Aeronautic Meeting

THE dates for the Aeronautic Meeting are announced in the Meetings Calendar on p. 216. In holding one session at Spokane on Sept. 23, the Aeronautic Meeting Committee feels that it is giving the aeronautic industry on the West Coast an opportunity to discuss matters of general engineering interest.

The principal meeting will, however, be held in New York City from Oct. 18 to 20. The technical program for this meeting covers practically every subject of major interest in aeronautic engineering, emphasis having been placed on problems that face the industry in design and operation. The complete announcement for the Aeronautic Meeting will be printed in the October issue of THE JOURNAL.

Roy D. Chapin

"IF sound and experienced policies are instituted, international mass salesmanship can help greatly in widening world demand. America cannot do this alone. Neither can Europe. Let us combine with Europe for the benefit of our export trade as well as theirs." With these words Roy D. Chapin, president of the National Automobile Chamber of Commerce, outlined a basis for increasing the wealth of not only a few countries but of all countries. Mr. Chapin has been identified with the automobile business for a generation and has done invaluable work in broad service relating particularly to highway development. He became associated with the Society in 1912 as a representative of the Hudson Motor Car Co. under its affiliate membership. He has spoken of the automobile industry as a business which measures time only by the rapidity with which any duty can be well accomplished. He said recently that the older men in the industry who seem to get real satisfaction out of their lives are those who have produced something that added to human happiness and let financial compensation come as a result. In his leadership Mr. Chapin is exemplifying the reduction to practice of salutary principles.

Safe Flying Wanted

A VITAL factor in the future development of aviation is the building up of confidence in the safety of flying. So long as ordinary life and accident insurance policies are voided by leaving the ground in an airplane, and so long as people generally look upon flying as taking their lives in their hands, the airplane suffers from a serious psychological handicap.

Accumulation of an impressive list of safe-flying records, like those made by the Air Mail pilots, will establish confidence. Each serious flying accident offsets thousands of miles of safe flying. The accident may be due to causes that can be thoroughly explained and that can be avoided in other flights, but the public is not well enough informed to discount such avoidable hazards. In spite of two previous disastrous failures, the brilliant success of five transoceanic flights did much to establish public confidence.

In his paper, printed in this issue of THE JOURNAL, A. H. G. Fokker mentions the need for safe airplane construction to build up public confidence. He also mentions the danger of loading a plane to the limit of its capacity. For any distance record-breaking flight, an airplane must be loaded to the limit at the start to carry the required quantity of fuel. This has been the cause of more than one wreck in taking off and in landing after an unpropitious start.

High Navy officials are quoted as saying that some curb must be placed on such flights. It is highly desirable that reckless and ill-advised attempts to break records shall be avoided. The subject is worthy of careful study, both to preserve human life and to accelerate the building up of public confidence.

European Trip, Nov. 2 to Dec. 12

MEMBERS of the Society who have expressed a desire to form a party to visit the World Motor-Transport Congress and the Commercial Motor-Transport Exhibition in London, in November, have received, besides the proposed itinerary, a copy of the formal announcement in which Horace Wyatt, organizer of this

year's Congress, requested that the Society be represented at that event. It is believed that others who have not signified their intention to make the trip may be considering the possibility of joining the Society's party, and such members are urged to communicate with Society Headquarters at once with a view to being kept informed regarding plans for the proposed visit.

Participation in the conferences of the World Motor-Transport Congress will engage the attention of the Society visitors on Nov. 14 to 16, after which an official visit will be made, Nov. 17, to the Commercial Motor-Transport Exhibition at Olympia. A joint meeting with the Institute of Transport and the Institution of Automobile Engineers has been scheduled for Nov. 22; a dinner to the Society of Motor Manufacturers & Traders for the 24th, and a professional session for the 25th. The Institution of Automobile Engineers will celebrate its 21st birthday, Nov. 30, with a dinner and a dance at which Society visitors will be guests of honor. Other days during the fortnight will be set aside for visits to factories and plants in London and elsewhere. Secretary Basil H. Joy, of the Institution of Automobile Engineers, has asked for suggestions regarding the plants that the Society's party would like to visit and has promised to do all he can to make the reunion a memorable success.

Education

MUCH of the criticism of education that one frequently hears grows out of an exaggerated notion of the transformation which some people expect a few years of education to work. Some college graduates are very bitter in their criticism of college education, protesting that they did not learn anything that did them any good. Perhaps they expected too much for the amount of effort put forth and tried to do too great a business on a small intellectual capital. Or perhaps such criticism is in part a pose; in certain circles it is now "the thing."

I suspect that there has long been more knowledge than intelligence in the world. The difficulty is that we frequently do not know how to use the knowledge we possess, for to use knowledge requires wisdom, and no one can give us wisdom. The beliefs we entertain and the deeds we perform or leave undone are the best measure of our intelligence.

Extravagant claims for education lead to pretense, to painful efforts at keeping up appearances, to exposure, and ultimate disillusionment. People have been led to expect too much of prevailing education. The longing for the irresponsibility of childhood is very common among mankind, and it gives rise to many comforting fictions which yield reluctantly to knowledge of facts.

It cannot be said that there has been a general gain in intelligence corresponding to the increase of specialized scientific knowledge. Failure of formal education is the result of the fact that educators frequently do not know what liberal education is. The isolated student, like the person learning to swim, makes much needless effort. He tries to stuff his head with learning. He needs time to meditate upon what he learns, to talk about it, to assimilate it, to see its relations to his knowledge and experience as a whole. Herein is the value of group discussion, where there is a real meeting of minds But it is not as groups that men may attain wisdom. With all the aid possible from others, education is necessarily an individual achievement.—Everett Dean Martin.

Society Activities Heralded Widely

NEWSPAPERS throughout the Country, and periodicals devoted to many different industries, generously chronicle the activities of the Society from week to week and from month to month. The appreciation of the Society is due to the editors of the periodicals and to the automobile editors of the newspapers for the large aggregate weekly volume of items published relating to its meetings, to papers presented at them and to the standardization and research work of the Society. An average of nearly 100 press clippings per week, all mentioning the Society, is received at the headquarters in New York City. These are from newspapers alone, as a rule, as no clipping service covering periodicals is used.

Owing to the technical nature of most of the papers and articles published in THE JOURNAL, as well as of the research and standardization work of the Society, a monthly press sheet is printed in which digests are given of the phases of the papers and work regarded as of most popular interest, this being written in language easily comprehended by the layman. These press sheets are mailed to several hundred newspapers, periodicals, engineering societies, colleges and universities, and Government departments and bureaus. Some of the universities and societies regularly post them on their bulletin boards. And by means of them the Government departments and bureaus keep posted on developments in the automotive engineering field. A number of periodicals in this Country and in England reprint, from time to time, complete papers that appear in THE JOURNAL.

For the 12 months of 1926 a total of 4550 press clippings of reprints of items taken from the sheets, special announcements of coming meetings and reports of meetings held were received. These were printed in 250 different newspapers in 40 States and in 60 different periodicals. That the chassis-assemblying contest at the Summer Meeting last May was of widespread interest is evident from the fact that 125 clippings, including 15 photographs of the event and as many group pictures of officers and prominent members of the Society in attendance, were received.

Clippings received each month that digest a specific paper presented at a National or a Section meeting are mailed to the author of the paper as a matter of interest and as a courtesy to him. This attention has been appreciated and is believed to aid in stimulating interest of authors and to be an added incentive to do the work required in the preparation of a serious technical paper before an engineering society.

The desirability of the Society's letting the world know what it is doing and the progress that is being made in automotive engineering seems to be conceded generally. Newspapers welcome the information, a fact that Section secretaries can properly take advantage of with the object of increasing Section membership and attendance at Section meetings.

ROY D. CHAPIN

Meetings Calendar

Production Meeting

Sept. 19 to 22, 1927

Cleveland Sessions
Hotel Winton, Sept. 19 and 20, 1927

The Stag Carnival
Rainbow Room, Sept. 20

Detroit Sessions
Hotel Statler, Sept. 21 and 22, 1927

Aeronautic Meeting

Spokane Session Sept. 23, 1927
New York Sessions Oct. 18 to 20, 1927

Visit to Aberdeen Proving Ground

Oct. 6, 1927

Transportation Meeting

Oct. 25 to 27, 1927
Hotel Sherman, Chicago

European Trip

Nov. 2 to Dec. 12, 1927

World Motor-Transport Congress
London, England, Nov. 14 to 16, 1927

Commercial Motor-Transport Exhibition
London, England, Nov. 17 to 26, 1927

Tractor and Stationary Engine Meeting

Dec. 1, 1927
Hotel Sherman, Chicago

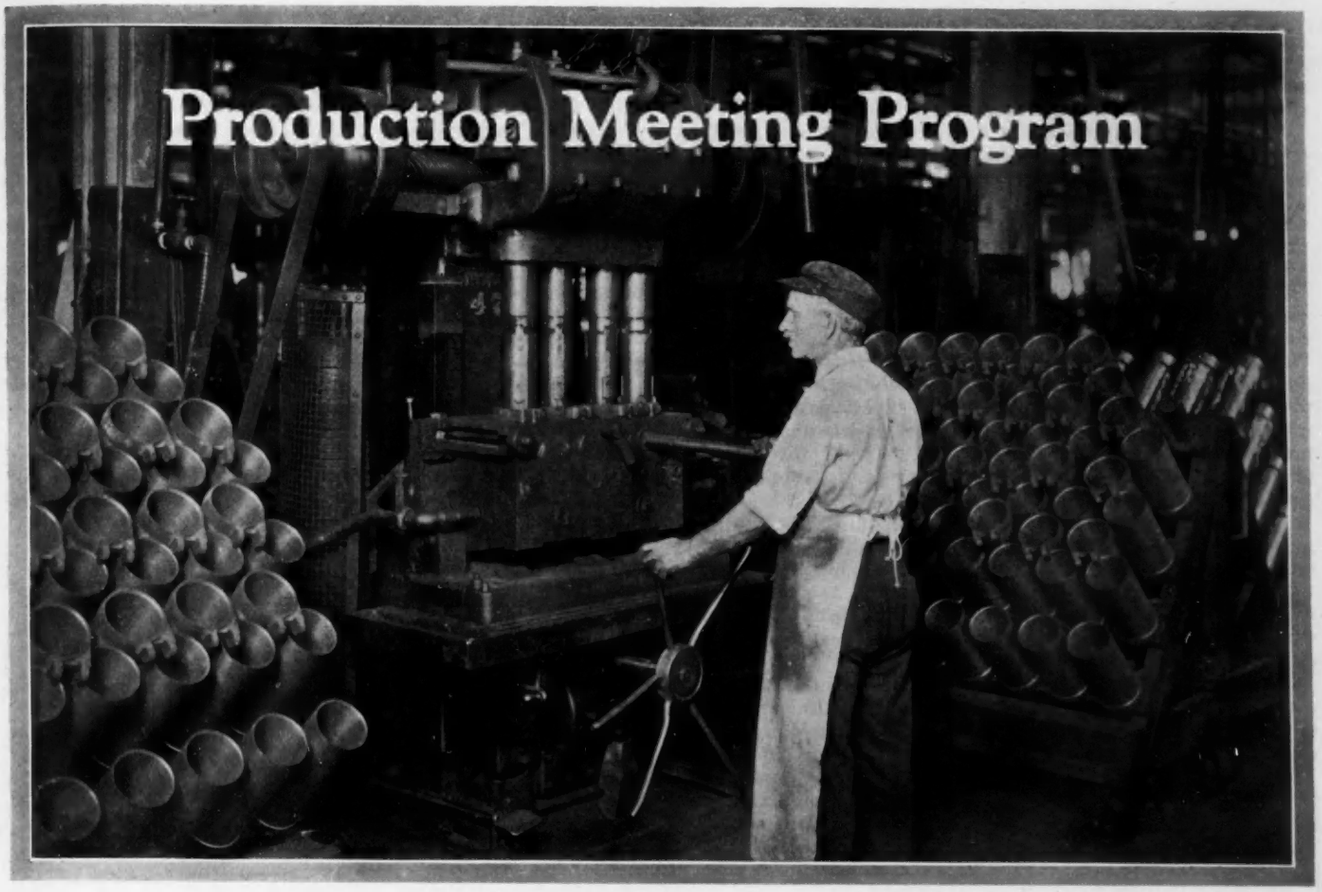
Sections Calendar

Milwaukee-Chicago Sections Outing

Sept. 14, 1927
Westmoor Country Club

Metropolitan Section Outing

Sept. 15, 1927
Manhasset Bay Yacht Club



Production Meeting Program

The 1927 Production Meeting of the Society establishes a precedent in that it will be a two-city meeting. The first 2 days' session will be at the Hotel Winton in Cleveland and the sessions on the last 2 days will be at the Hotel Statler in Detroit. The Stag Carnival, initiated last year in Chicago at the Chez Pierre, is to be held on the evening of Sept. 20 in the Rainbow Room of the Hotel Winton.

The Production Meeting is having a greater appeal to members each year as the importance of production engineering increases. A recent analysis of the Society membership indicates that approximately 21 per cent of the members are interested primarily in production. A large number of the other members are interested in production indirectly, and the Production Meetings afford them an opportunity to obtain a better appreciation of the problems facing the production engineers and the methods used to solve them.

The Cleveland Sessions

The first session of the Production Meeting will be held Monday morning at 9 a.m. in the ballroom of the Hotel Winton. The papers to be presented are by George T. Trundle, Jr., on Net Profit from Modern Machine-Tools, and Lee M. Beatty, on Manufacturing Methods Used in Building the Wright Whirlwind Engine. Mr. Trundle is a consulting industrial engineer and his experience in production is indicative that his paper will be of great value to production engineers.

Mr. Beatty's paper should prove both instructive and interesting. As is well known, the Wright Whirlwind engine was used by Lindbergh, Chamberlin, Byrd, Maitland and Smith in their recent transoceanic flights. It represents the development of many years of intensive research, and the manufacturing methods used in producing such an engine will be of real interest.

Two papers will be presented at the evening session, one by D. W. Ovaitt on Non-Productive Materials, and the other by E. P. Blanchard on Integrated Production. Mr. Ovaitt is an efficiency engineer connected with the Buick Motor Co. and his paper represents several years of study in connection with the possibilities of decreasing production costs by the simplifying and handling of non-productive materials. The savings that have been made possible by the Buick Motor Co. as a result of Mr. Ovaitt's work have been astonishing and the methods used in making these savings possible should warrant the attendance of every production engineer at this session.

E. P. Blanchard, of the Bullard Machine Tool Co., needs no introduction to production engineers. His paper on Integrated Production represents the conclusions of many years of study. An outline of his paper appears in the Production Engineering department of this issue.

The Machine-Tool Session is to be held Tuesday morning. The first of the three papers to be presented is by R. C. Deale, of the Niles-Bement-Pond Co., on the Application of Electric Motors to Machine-Tools. Mr. Deale outlines the difficulties that have been experienced by the machine-tool builders in obtaining electric motors with standardized mounting-dimensions. This condition has made it difficult for machine-tool users to replace electric motors that have failed during production. Mr. Deale presents an analysis of machine-tool electric-motor practice and indicates the feasibility of standardizing such motors, but intimates that this cannot be brought about without the support of the production engineers of the automotive industry.

Two papers will be presented at this session on developments in grinding or honing. M. C. Hutto, of the Hutto Engineering Co., Inc., will discuss Developments in Cylinder Grinding and the difficulties that have been experienced in actual production. His paper will be followed by a discussion by P. H. Walker, ceramic engineer of the Carborundum Co., on the processes used in developing the stones made for cylinder-grinding machines. Mr. Jenne, also of the Carborundum Co., will demonstrate one of these machines following the presentation of the paper.

The other paper will be by L. A. Becker, chief engineer of A. P. Schraner & Co., on the subject of External Honing. Mr. Becker's paper describes the process, the result it accomplishes and its advantages. Photomicrographs of ground

and honed surfaces will be shown with other illustrations. Although the paper deals largely with crankshaft honing, research now being carried on that indicates many other possible applications for external honing is outlined.

The wider use of external honing and internal grinding indicates that the Machine-Tool Session will be one of the best-attended sessions of the Production Meeting and, owing to differences of opinion that exist in this phase of production work, a lively discussion is anticipated.

The Detroit Sessions

The first session in Detroit will be held Wednesday afternoon at the Hotel Statler, and is to be devoted to a discussion of metallurgy and grinding. The first paper, by J. M. Watson, metallurgical engineer for the Hupp Motor Car Corporation, is on the subject of the Relation of Metallurgy to Production. Mr. Watson indicates in his paper that the metallurgical department has become an integral part of production and that, in addition to the work for which it is directly responsible, the department is in a position to assist all other departments.

Following Mr. Watson's paper, E. J. Janitzky, metallurgical engineer of the Illinois Steel Co., will discuss the research now being conducted by a special committee of the S.A.E. Iron and Steel Division to determine the desirability of basing the S.A.E. Physical-Property Charts on "frequency curves." Mr. Janitzky's paper will be of exceptional interest to every member who has used these charts.

A third paper to be presented at this session discusses recent developments in grinding practice and outlines research now being carried on that may develop new grinding processes. This paper will be by O. A. Knight, of the Norton Co.

At the Wednesday evening session, A. R. Glancy, president of the Oakland Motor Car Co., will discuss production engineering and the position of the production engineer in the automotive industry from a management viewpoint. H. L. Miner, manager of the safety and fire protection division of E. I. du Pont de Nemours & Co., will present a paper on Fire Hazards Incidental to the Spraying of Inflammable Finishes. This subject is of vital importance and has received a great deal of study in recent months, following the disaster at the Briggs Mfg. Co. plant in Detroit. The Wednesday evening session might well be called a management session, as it will deal with production from the management viewpoint.

Following the two papers, an intensely interesting motion-picture called The Age of Speed will be exhibited through the courtesy of the Norton Co. This picture shows all phases of transportation and production and is sure to appeal to everyone attending the session.

At the Time-Study Session on Thursday evening, Sept. 22, two papers will be presented, one by J. C. Mottashed on the Relation of Time-Study to Management, and one by E. J. Frounfelker on the Relation of Time-Study to Labor Budgets. Mr. Mottashed is connected with the Hudson Motor Car Co. and Mr. Frounfelker with the Continental Motors Corporation.

Preprints of Papers

Papers to be presented at the meeting will be preprinted and copies sent, upon request, to members interested in discussing the subjects dealt with at the various sessions.

The Stag Carnival

On Tuesday evening, the Society's second Stag Carnival will be held in the Rainbow Room of the Hotel Winton. The Production Meeting Subcommittee intends to make this the most important social event in the S.A.E. Calendar. L. L. Williams, of the Chandler-Cleveland Motors Corporation, has been appointed Chairman of the Entertainment Committee, and under his direction an array of talent is being booked that

PRODUCTION MEETING PROGRAM

Cleveland Sessions—Hotel Winton

Monday, Sept. 19

9:00 a. m.—Opening Session
E. P. Blanchard, Chairman
Net Profit from Modern Machine-Tools—George T. Trundle, Jr., Trundle Engineering Corporation
Manufacturing Methods Used in Building the Wright Whirlwind Engine—Lee M. Beatty, Wright Aeronautical Corporation

7:30 p. m.—Evening Session
W. G. Careins, Chairman
Non-Productive Materials—D. W. Ovaitt, Efficiency Engineer, Buick Motor Co.
Integrated Production—E. P. Blanchard, Bullard Machine Tool Co.

Tuesday, Sept. 20

9:00 a. m.—Machine-Tool Session
K. H. Condit, Chairman
Application of Electric Motors to Machine-Tools—R. C. Deale, Niles-Bement-Pond Co.
Developments in Cylinder Grinding—M. C. Hutto, Hutto Engineering Co., Inc.
Processes Used in Making Stones—P. H. Walker, Ceramic Engineer, Carborundum Co.
A demonstration of a tamping machine for obtaining uniform hardness of stones will follow this paper.
External Grinding—L. A. Becker, Chief Engineer, A. P. Schraner & Co.

6:30 p. m.—The Stag Carnival
Rainbow Room—Hotel Winton

Detroit Sessions—Hotel Statler

Wednesday, Sept. 21

2:00 p. m.—Steel Session
Frank P. Gilligan, Chairman
Relation of Metallurgy to Production—J. M. Watson, Metallurgist, Hupp Motor Car Corporation
Frequency Curves as a New Basis for S.A.E. Physical-Property Charts—E. J. Janitzky, Metallurgical Engineer, Illinois Steel Co.
Developments in Grinding—O. A. Knight, Norton Co.

7:30 p. m.—Evening Session
John Younger, Chairman
Production Engineering—A. R. Glancy, President, Oakland Motor Car Co.
Fire Hazards Incidental to the Spraying of Inflammable Finishes—H. L. Miner, E. I. du Pont de Nemours & Co.
The motion picture, The Age of Speed, will be shown following the second paper

Thursday, Sept. 22

7:30 p. m.—Time-Study Session
Eugene Bouton, Chairman
Relation of Time-Study to Management—J. C. Mottashed, Hudson Motor Car Co.
Relation of Time-Study to Labor Budgets—E. J. Frounfelker, Continental Motors Corporation

will make the revue an event that future Production Meeting Committees will find it difficult to equal. The revue will follow immediately at the close of the dinner; in fact, it is expected that some of the acts cannot be delayed until then. All will be run off with true production-engineering precision so that the last act will be over at 11 p.m. This will allow 30 min. for the members who are to leave on the Detroit boat to reach the D & C Navigation Co. dock in time for sailing.

Special invitations by the Subcommittee to attend the S.A.E. Stag Carnival have been mailed to the members of the National Machine-Tool Builders' Association, and it is hoped that it will be possible for a large number of the members to be present, as closer personal contact between the machine-tool builders and the automotive production engineers will result in better appreciation of each other's problems and make their solution easier.

Machine-Tool Exhibitions

Real difficulty will be experienced during the Production Meeting in both Cleveland and Detroit to find sufficient time to attend the exhibitions and technical sessions scheduled by the National Machine-Tool Builders' Association, the American Society for Steel Treating, the American Welding Society, the Institute of Metals, and the Society. In Cleveland, the Production Meeting sessions have been scheduled for the morning to permit members to attend the Machine-Tool Exhibition in the afternoon. In Detroit, no sessions will be held in the forenoons, which will afford time for visits to the National Steel and Machine-Tool Exposition. Wednesday morning has also been held open, as many Society members will desire to attend the American Welding Society's session on Automobile Welding, the program for which includes a paper on Car Welding by Victor Willoughby, general mechanical engineer of the American Car & Foundry Co., and a paper on Automobile Welding by W. C. Happ, chief engineer of the department of methods and standards of the Studebaker Corporation of America. This meeting will be held at the Book-Cadillac Hotel.

The Arabian Ball of the American Society for Steel Treating will be held Wednesday evening, and the Annual Dinner on Thursday evening at the Hotel Statler.

Aberdeen Proving-Ground Visit

Plans for the Ninth Annual Meeting of the Army Ordnance Association, to be held at Aberdeen Proving Ground, Maryland, Thursday, Oct. 6, 1927, to which members of the Society are invited, indicate that the affair will be one of the most interesting demonstrations of military equipment since the World War. The annual meetings of the Association attract increasing interest from year to year, not only because of their appeal to American citizens interested in the military phases of National defense, but also because of their instructive value to executives and engineers of American industry.

This year the meeting will include demonstrations of practically every type of Army ordnance, beginning with the 16-in. gun and ranging down to the smallest rifles and pistols. One particularly interesting exhibit will be a huge Krupp howitzer, one of three allotted the Allies after the signing of the Armistice. It fires on its own wheels and requires five transport wagons for shipment.

Through the cooperation of the various branches of the Army, the annual meetings of the Army Ordnance Association take on the appearance of a real Army show. In addition to ordnance equipment, demonstrations are also given by the Chemical Warfare Service, the Air Corps, the Signal Corps, the Field Artillery, the Coast Artillery, and the Quartermaster Corps.

This year's program includes anti-aircraft firing at a target towed by an airplane, which is intended to show the remarkable strides that have been made both in the improvement of anti-aircraft guns and fire-control instruments and in the training of personnel. A new feature of the meeting this year will be the serving of all meals by the Quartermaster Corps. Under the supervision of the Quartermaster General of the Army, elaborate arrangements are being made for the meeting, and real Army meals in Army style will be served.

Unless you have attended one of the recent demonstrations at Aberdeen, it is impossible to appreciate the program, admirably described in the following paragraphs by a member of the Army Ordnance Association who has attended many of the meetings:

> Ordnance day at Aberdeen is one of continuous demonstrations beginning at 10:00 a.m. and concluding at about 7:30 p.m. It is not a day of speeches and papers, but an occasion when the Army brings forth in continuous procession the weapons and equipment which have enabled it to reach its present high state of efficiency.
>
> If you have never seen or heard the big guns in action there is something in store for you at Aberdeen. They will make the earth tremble. If you have not seen the big Army bombing-planes dropping demolition bombs you have missed something. If you have never seen a real aircraft demonstration, bombers big

and little, parachute jumps and the rest, you should come to Aberdeen on Oct. 6. It will be a revelation to you.

We have heard a great deal about aircraft being superior to guns, that airplanes cannot be hit and so on. Come and see. Watch the planes go up towing a target not half the size of a real airplane. Watch the target trace through the clouds and then see the anti-aircraft artillery go after it. They place their shots with micrometer precision and you will agree that it is well that the target is only a target.

Remember that all this takes place on a snappy October morning. Tramping around in the brisk air will make you hungry. So off the big crowd goes to a real Army dinner, prepared by Army cooks and bakers serving Army food in Army style. There will be plenty of room, plenty of food and plenty of good time.

In an hour or so the show starts again, so down we go. But it should be said here that Aberdeen Proving Ground covers slightly more than a city block; as a matter of fact, it embraces 70,000 acres and has its own railroad, so when we say we "go here" or "go there" at Aberdeen we mean we go 1 or perhaps 5 miles down the range to watch this or that demonstration. Anyway, after dinner the show begins again. Out comes the automotive equipment, tanks big and little, tractors hauling huge howitzers, guns propelling themselves, cross-country cars, cargo trucks; all types of automotive equipment of the Army. You see them climb hills and cross swamps, the tanks crawl over all kinds of obstructions, the cross-country cars go up hill and down dale. Meanwhile, the demonstrations of smaller guns are getting under way—all kinds, all sizes, all shapes; machine-guns, rifles, field guns, howitzers, mortars—all of them pumping away.

Next we go to the Ordnance Museum where one can see captured guns and freak guns, old tanks and new tanks, repair-shops on wheels, guns, ammunition, bombs —everything. Study them all you please; the Army wants civilian America to see the works, for, after all, civilian America must know how to make ordnance if war ever comes again.

And so the day goes like clockwork, a band concert now and then, a good supper, and more anti-aircraft night firing when the giant searchlights pick up the tiny targets in the clouds and the guns bark their salvos at the make-believe invaders. Wonderful precision, wonderful team-work!

The Pennsylvania Section is planning to make the trip to Aberdeen a Section Meeting event, and special transportation arrangements are being made so that the Section members can go in a body. The visit of the Washington Section to the Proving Ground will be preceded by a Section meeting on the night before with a speaker from the Ordnance Department. All members will soon receive personal invitations and complete details from the Army Ordnance Association.

THE EXPANSION OF OUR AERIAL DEFENSE

SPEAKING at a luncheon in Yonkers, N. Y., Assistant Secretary of War F. Trubee Davison stated that July 2 marked the first anniversary of the adoption by President Coolidge and by Congress of the 5-year Army Air Corps development-program. The last year, he said, had been productive of results, and the new year will produce more men, more equipment, better Army fields; in short, more progress. With the start of the new fiscal year, $21,891,000 is available for continuation of Army Air Corps development. This is in addition to an even greater sum in general appropriations for pay of the Army, subsistence, barracks, quarters, general transportation, military equipment, and accessories.

The following are the highlights of the record of Army Air Corps expansion and achievement during the last 12 months:

(1) Orders placed for 50 pursuit, 40 attack, 10 transport, 80 observation, 110 training, and 9 amphibian airplanes. Of these, 135 have been delivered. The balance will be forthcoming in the near future

(2) Replacing war-time wooden training airplanes with modern equipment for Reserve and National Guard flying. After Sept. 1, not a single "Jenny" will be in service. The discarding of these airplanes began on June 1

(3) The development of new bombardment and attack airplanes that are far superior to those now in use

(4) Establishing a new training school for flying cadets at March Field, California, and expanding training facilities at Kelly Field and Brooks Field, Texas

(5) Completion of the new establishment of the Army Air Corps Materiel Division at Wright Field, near Dayton, with every modern facility for experimental testing and development

(6) Participation by 109 Army airplanes in maneuvers near San Antonio, Tex., in conjunction with Second Division troops

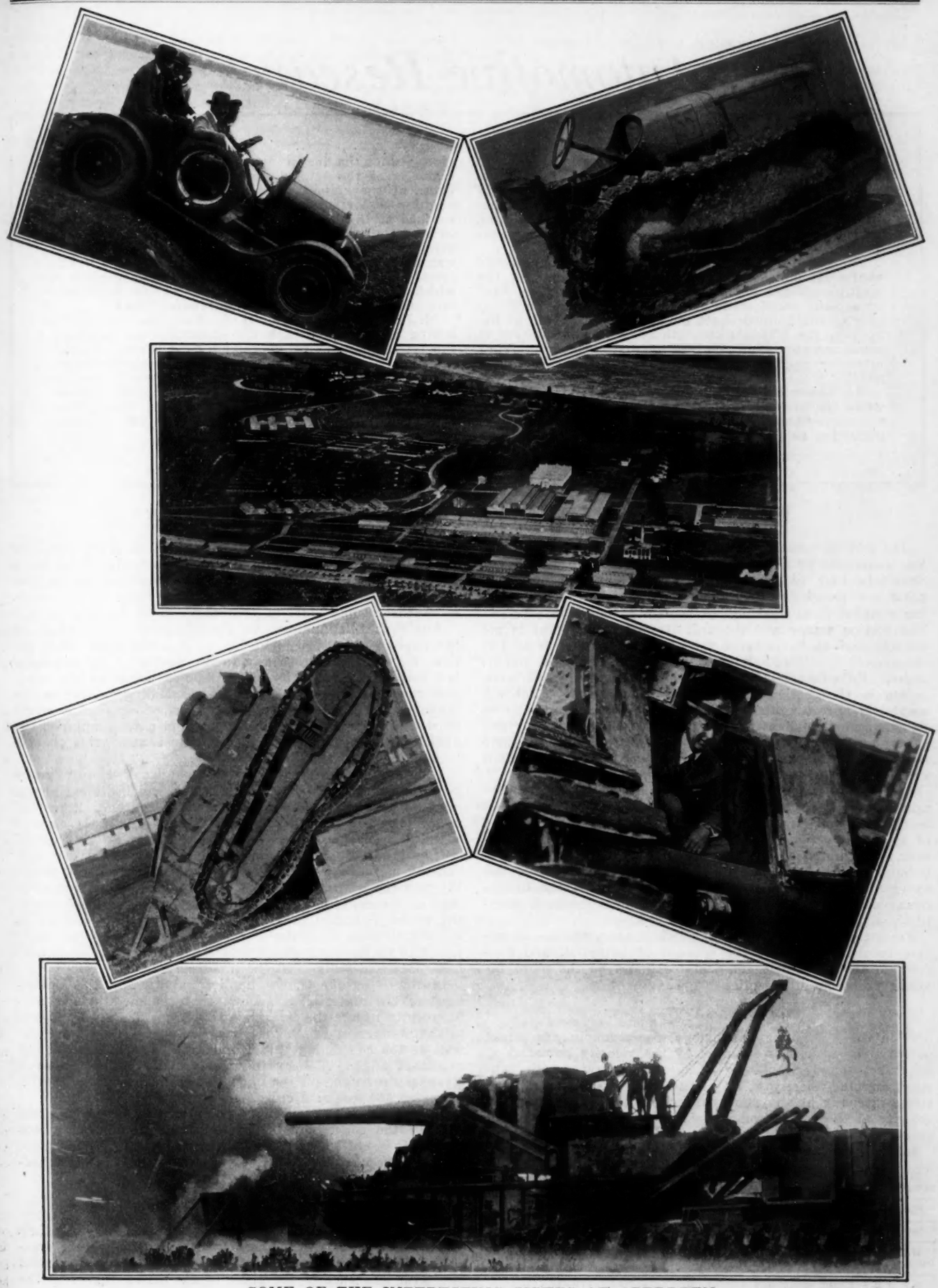
(7) The successful culmination of various Army flying-projects, including, besides the California-Hawaii flight, the Pan-American Good-Will mission and two spectacular flights by pursuit airplanes, one into Canada in zero weather, and one from Michigan to Texas, about 1300 miles, in less than 12 hr.

(8) Inauguration of policies that will increase participation of Reserve Officers and National Guard air-units in military flying

(9) Many valuable contributions toward engine development, airplane construction, aerial navigation, and aerial photography as the result of research work performed by the Materiel Division

The second year of the Army Air Corps development-program started in July. Out of the $21,891,000 set aside for the Army Air Corps development, $12,000,000 is authorized for the purchase of 590 airplanes of various types. Authorizaton is also given to increase the number of our flying officers to 1100 and the enlisted strength to 10,008, and to place 110 Reserve officers on active duty for 1 year. Among other important appropriations are the following: $2,200,000 for experimental and research work, $1,062,000 for improving Army Air Corps fields and technical construction; and $475,000 for lighter-than-air equipment, including $200,000 for the purchase of helium.

The first stage of the Army Air Corps development-plan has been completed. The second has started. There is every indication that with the support of Congress and an air-minded public, this Country, by the end of 1932, will have attained the air-defense goal set by the Act of July 2, 1926. At that time, if the 5-year plan is realized, this Country will have an Army Air Corps of 17,650 flying officers, 550 Reserve officers on active duty and 15,000 enlisted men. The flying equipment will consist of 480 pursuit, 95 attack, 195 bombardment, 59 transport, 412 observation, 72 amphibian, and 479 training airplanes, and 110 aircraft of various types in war reserve.—Air Corps News Letter.



SOME OF THE INTERESTING SIGHTS AT ABERDEEN

Automotive Research

At the Research Session of the Summer Meeting at French Lick Springs, Ind., C. W. Spicer[1] in a paper entitled Torsional Strength of Multiple-Splined Shafts[2] presented results of a number of tests which supplemented an earlier series of tests, conducted by him, directed toward the same subject and previously reported.[3]

The results of these practical tests of actual splined shafts all indicate that, while the elastic-limit of the multiple-splined shaft is considerably less than that of a plain round shaft of diameter equal to the diameter of the splined shaft measured at the base of the splines, the ultimate-strength of the splined shaft is much greater than that of a plain round shaft of diameter equal to the base diameter of the splined shaft.

Mr. Spicer explains these results on the theory that, when the shaft is under torsional load, the strain in the outer fibers is about the same for a given angular-distortion as it would be in a shaft of plain circular cross-section having a diameter equal to the outside diameter of the splined shaft and therefore the outer fibers of the splines reach their elastic-limit through angular distortion before the elastic-limit has been reached at the base of the splines, nearer the neutral axis of the shaft; but when the strain is carried beyond the elastic-limit, with a ductile material such as was used in these tests, the splines, assuming a spiral form, gradually take on a tensional stress, a part of which assists the torsional capacity of the solid portion of the shaft in carrying the torsional load.

M. J. Zucrow[4] and Prof. H. A. Huebotter[5] in the following analysis approach the question from a purely theoretical standpoint indicating by analogy through their study, which applies only within the elastic range, that the low elastic-limit of the splined shaft may be readily accounted for by the high localized stress-intensity at the sharp inner-corners of the splines when the fillets there are omitted or made of small radius.

TORSIONAL STRENGTH OF SPLINED SHAFTS

The general mathematical theory of elastic torsional stress was developed by Barré de St. Venant in 1855. He showed definitely that non-circular sections which are originally plane and perpendicular to the shaft axis before the twisting moment is applied do not remain plane when stressed. The section warps and the unit stress at any point is not proportional to its distance from the axis, as it is in circular sections. This sectional warping is of utmost importance. Its effect is to increase the shear stress at some points in the section and diminish it at others. For example, in a rectangular shaft the unit shear-stress attains its maximum value at the midpoints of the long faces and is zero at the corners. Shafts of elliptical cross-section have maximum stresses at the ends of the minor axes and minimum stresses at the ends of the major axes.

Although mathematical analyses have been made for certain regular shapes of non-circular shafts, no purely mathematical analysis is possible for the irregular sections that are of special interest to engineers. St. Venant's theory, however, has pointed the way to study the torsional-stress distribution in a shaft by certain analogies which enable one to visualize this distribution. One of these is the hydrodynamic analogy; another, the stretched membrane or soap-film analogy.

From the mathematical point of view, the problems of torsion involve essentially the concept of potential, and conform to the same mathematical treatment as the more familiar problems in potential.

Hydrodynamic Analogy

If in the hydrodynamic analogy, for example, the stress potential in a shaft is replaced by the velocity potential of a perfect liquid circulating at a uniform rate, with constant angular-velocity at all points on the same radius, the stress intensity at any point can be represented by the fluid velocity at the corresponding point of the hypothetical shell enclosing the liquid.

In the cylindrical shell shown in the upper left diagram in Fig. 1 the area of the path about the axis is uniform, and consequently the velocity at any point is proportional to its distance from the cylinder axis. In the corresponding torsional problem of a circular shaft, the stress at any point is likewise proportional to its distance from the shaft axis.

Applying this analogy to the elliptical cross-section in the upper right diagram in Fig. 1, it is seen that, since the flow-rate of fluid across any radius vector to the boundary is a constant, the velocity of the fluid at points on the minor axis must be greater than at corresponding points on the major axis. Consequently, the region of maximum stress is at the minor axis, as already pointed out. Similarly, the analogy when extended to rectangular shafts gives the results previously described.

It is well known that a small hole bored longitudinally near the surface of a shaft, or a keyway cut in its periphery, may set up localized stresses of great magnitude. Referring to the lower diagram in Fig. 1, it is seen that if the corners *a* and *b* of the keyseat are sharp, the velocity at these points will be infinitely great, as the fluid must move at very high velocity at the seat to maintain the same rate of flow across the sections *ob* and *oc*. The laws of hydrodynamics show that at the corners *d* and *e* there is no flow of fluid; hence the velocity at these points is zero. From this analogy, it is evident that the outer corners of the keyway are subjected to no shearing stress whatever, while there are enormous localized stresses at the inner corners.

Inasmuch as the theory applies only within the elastic-limit of the material, it follows that the metal yields sufficiently to relieve the stresses at *a* and *b*. This is analogous to the manner in which the streamlines of a fluid leave the wall of the containing vessel and initiate turbulence at the reentrant angle. The hydrodynamic analogy also makes it clear why rounding-off the inner corners of a keyway greatly increases the torsional resistance of the shaft.

The substitution of velocity potential for stress potential clarifies the conception of stress distribution in a twisted shaft. It is not so well adapted, however, to the qualitative determination of the localized stresses as is the stretched-membrane analogy.

Quantitative Stretched-Membrane Analogy

If a membrane or a soap-film is stretched across a hole of the same shape as the shaft section, and the proper pressure differential is applied to it, the contours of the depressed film with reference to the plane of the orifice represent the

[1] M.S.A.E.—Vice-president and chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J.

[2] See The Journal, June, 1927, p. 739.

[3] See The Journal, February, 1921, p. 129.

[4] M.S.A.E.—Research assistant, Engineering Experiment Station, Purdue University, West Lafayette, Ind.

[5] M.S.A.E.—Chief engineer, Butler Mfg. Co., Indianapolis.

conjugate function of the stress potential. Proper measurements of the deflection and slope of the film surface permit the calculation of the shearing stresses. This method has been used to determine the effect of the radius of curvature of fillets placed at the corners *a* and *b*, in Fig. 1, of a slotted shaft. The analysis was made for a 10-in.-diameter hollow shaft with a 5.8-in. bore. The keyway was 2.5 in. wide and 1.0 in. deep. Fillet radii of 0.1, 0.2, 0.4 and 0.7 in. were investigated.

[7] M.S.A.E.—Technical assistant to president, General Motors Corporation, New York City.

[8] See THE JOURNAL, May, 1921, p. 443.

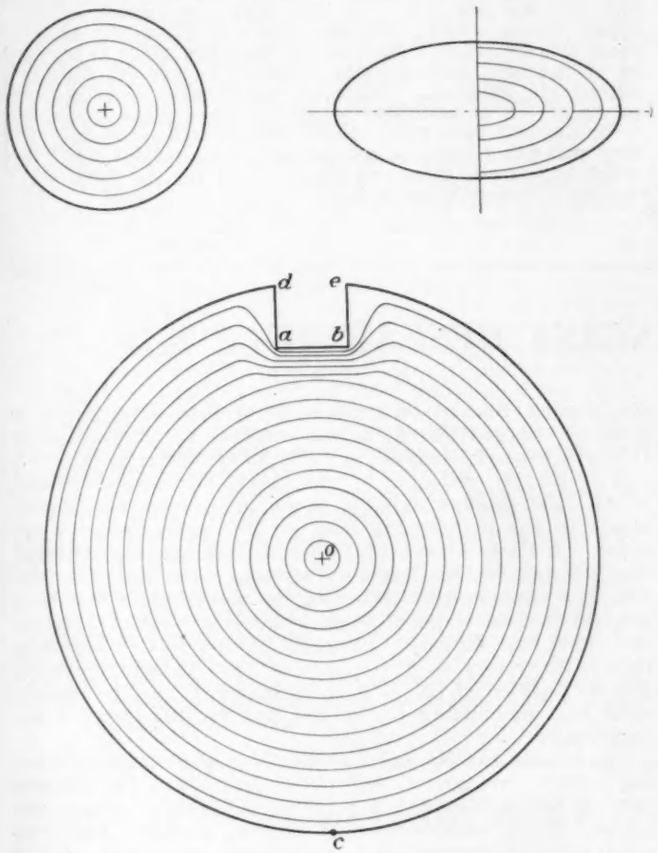


FIG. 1—HYDRODYNAMIC ANALOGY PRESENTED DIAGRAMMATICALLY

Employing the Hydrodynamic Analogy in Treating Torsional Phenomena as a Concept of Potential, the Stress Potential in a Shaft of Circular Cross-Section May Be Considered as Replaced by the Velocity Potential of a Fluid Circulating at a Uniform Rate, with Constant Angular-Velocity at All Points Having the Same Radius. The Stress Intensity at Any Point Is Represented then by the Fluid Velocity at the Corresponding Point of the Hypothetical Shell Enclosing the Liquid. Thus, in the Cylindrical Shell, Shown in the Upper Left Diagram, the Area of the Path about the Axis Is Uniform, and Consequently the Velocity at Any Point Is Proportional to Its Distance from the Cylinder Axis. In the Corresponding Torsional Problem of a Circular Shaft, the Stress at Any Point Is Likewise Proportional to Its Distance from the Shaft Axis. Applying This Analogy to the Elliptical Cross-Section in the Upper Right Diagram, Since the Flow-Rate of Fluid across Any Radius Vector to the Boundary Is a Constant, the Velocity of the Fluid at Points on the Minor Axis Must Be Greater than at Corresponding Points on the Major Axis. Consequently, the Region of Maximum Stress Is at the Minor Axis. In the Lower Diagram It Is Seen that for the Keyseated Section, the Fluid Must Move at Very High Velocity at the Seat To Maintain the Same Rate of Flow across the Sections *ob* and *oc*. The Laws of Hydrodynamics Show that There Is No Flow of Fluid at the Corners *d* and *e*, Hence the Velocity at These Points Is Zero. If the Corners *a* and *b* Are Sharp, the Velocity at These Points Will Be Infinitely Great. From This Analogy, It Is Apparent that the Outer Corners of the Keyway Are Subjected to No Shearing Stress, While There Are Enormous Localized Stresses at the Inner Corners

TABLE 1— MAXIMUM SHEAR-STRESS FACTORS[6]

Fillet Radius *r* for Keyway 2.5 In. Wide by 1.0 In. Deep in a Hollow Shaft of 5.8-In. Bore by 10.0-In. Diameter, In.	Ratio of Stresses at Inner Corners of Keyseat, of Shaft and Fillets of the First Column, to Maximum Stresses Produced by the Same Torsional Moment in Plain Tubular Shafts with 5.8-In. Bore	
	Shaft with 8-In. Outside-Diameter	Shaft with 10-In. Outside-Diameter
0.1	2.26	5.40
0.2	1.40	3.35
0.3	1.11	2.65
0.4	0.96	2.30
0.5	0.88	2.10
0.6	0.82	1.95
0.7	0.80	1.90

[6] The first column gives the radius of fillets for the corners *a* and *b*, lower diagram in Fig. 1, of a keyway 2.5 in. wide and 1.0 in. deep, of a hollow shaft of 10.0-in. outside-diameter and 5.8-in. inside-diameter. The second column presents the ratio of the stresses at the inner corners of the keyseat, with the shaft and fillets of the first column, to the maximum stresses produced by the same torsional moment in an ordinary tubular shaft with 5.8-in. bore and 8.0-in. outside diameter. The third column presents the ratio, similar to that of the second column, for the shaft and fillets of the first column, to the maximum stresses produced by the same torsional moment in an ordinary tubular shaft with 5.8-in. bore and 10.0-in. outside diameter.

CONCLUSIONS

The results of the study are presented in Table 1. The stresses at the inner corners of the keyseat are expressed as ratios of the maximum stresses produced by the same torsional moment in two ordinary tubular shafts with 5.8-in. bore and diameters of 8 and 10 in. respectively. The outstanding deduction from this research is that a 0.35-in.-radius fillet is required to make the 10-in-diameter splined shaft as strong as a hollow circular shaft of 8-in. diameter.

It is hoped that this discussion may help to explain why the elastic-limit of the multiple-splined shaft was lower than that of the circular shaft with diameter the same as the root-diameter of the splined shaft. If small fillets were used, or none at all, the high localized stress-intensity at the inner corners of the splines must have exceeded the unit stress at the bottom center of the slots.

The fatigue effect of these localized stresses was mentioned by H. M. Crane[7] in his discussion of Mr. Spicer's paper as follows:[8]

> The effect of repeated stress on splined shafts . . . is distinctly to enhance the effect found on a straight torsional test, especially if the fillets on the corners are not amply great. We had a shaft break in torsion under these conditions. It looked like a perfectly good pie cut into segments, with cracks leading from the center to the corners of the spline.

Beyond the elastic-limit the discrepancy in the stress distribution over the periphery of the splined shaft is probably not so pronounced.

The mathematical treatment of this subject can be found in A. G. Webster, Dynamics; S. P. Timoshenko and J. M. Lessels, Applied Elasticity; H. Lamb, Hydrodynamics; E. Townsend, Functions of a Complex Variable; C. Drysdale, Mechanical Properties of Fluids.—M. J. Zucrow and H. A. Huebotter.

Engine power is an expression that has a wide range of meaning. In its most fundamental sense, it is the capacity for doing work developed in the engine cylinders and is limited by the breathing capacity of the engine, that is, its rate of air consumption. In its more derived significance, it means not capacity but accomplishment, and becomes a more and more comprehensive term with the increasing number of factors affecting achievement included in its definition. Perhaps the most complex criterion of engine power, including the greatest number of modifying factors, is the ability of the engine to propel a vehicle up a hill.

Methods of measuring engine power at both ends of the scale are included in the contributions made this month to Automotive Research. H. A. Huebotter[9] describes a positive rotary-displacement measuring apparatus designed to overcome the objections often raised to the use of the customary type of air-meter in the induction system. Prof. E. H. Lockwood[10] expounds a method for computing the hill-climbing ability of a car from data that are easily obtainable by any investigator on a hill of any known grade.

Both of the contributions describe methods for attaining greater accuracy or simplicity of operation evolved by investigators in the course of their work; and the methods described are easily applicable by others having similar problems to solve. They help to make this department fulfil one of its aims, which is to be of practical assistance to research workers in the automotive industry. If those who desire to make comments on or additions to these or any other contributions will send them to the Research Department, they will bring closer a realization of the second aim, which is to make these columns a forum for the interchange of research ideas.

AIR-METER FOR ENGINE RESEARCH

The internal-combustion engine is primarily an air engine. More than 97 per cent by volume of the charge that passes through the inlet valves is air. The more rapid the rate of air consumption is, the greater the power output of the engine will be. This being the case, the quantity of air inducted into the cylinders is of vital interest in engine development. The design of the gas passages; the diameter, lift and timing of the valves; and the choice of the carbureter all affect the volumetric efficiency and therefore the power. An accurate air-meter aids in the study of these parts individually, irrespective of other factors that may influence the power.

Valid objections often raised against the use of an air-meter in the induction system are that the meter is unwieldy, requires frequent calibration and causes a pressure loss at the carbureter. In an endeavor to overcome these failings, a positive rotary-displacement meter was constructed, tested, and put into service at the Engineering Experiment Station of Purdue University. The meter is portable, rugged and accurate; requires no pressure drop in operation and has given satisfaction in research.

[9] M.S.A.E.—Chief engineer, Butler Mfg. Co., Indianapolis.

[10] M.S.A.E.—Associate professor of mechanical engineering, Yale University, New Haven, Conn.

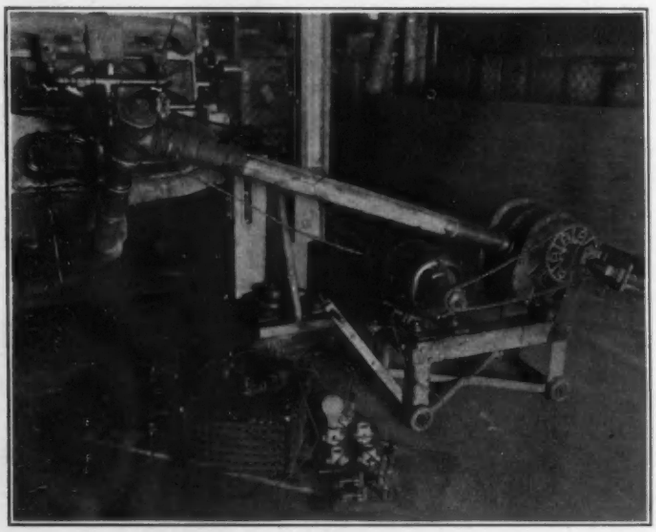


FIG. 2—POSITIVE ROTARY-DISPLACEMENT AIR-METER APPLIED TO A TEST ENGINE

On the Movable Stand at the Right Is Mounted the Air-Meter and the Direct-Current Electric Motor by Which It Is Driven with Exactly Enough Torque To Overcome the Friction. In the Foreground Are the Field and Armature Rheostats for the Control of the Motor Speed

The general principle of the rotary-displacement meter is not new, similar units in large sizes being used extensively in gas plants; but some of the minor features are novel. A Roots blower of 1/5-cu. ft. nominal displacement was selected for the metering element. The internal friction was minimized by mounting the rotors on self-aligning annular ball-bearings and by preventing contact between the rotors and the case. Slippage was reduced by carefully fitting the rotors with the smallest practicable clearance. The cooperation of the P. H. & F. M. Roots Co., of Connersville, Ind., in building the special unit for the meter is acknowledged.

The blower can be made to function as a meter by forcing a fluid through it; but meter torque can be obtained only at the expense of a pressure differential across the rotors. Even when revolving with no external load, the small internal friction causes a pressure drop which, at low flow-rates, may permit an excessive proportion of the fluid to leak through the interstices about the rotors. The smaller the meter is and the lower the rate of air-flow with unsealed rotors, the greater the relative slippage is likely to be.

ELIMINATION OF SLIPPAGE ERROR

To eliminate the relative-slippage error, the meter was driven by a direct-current electric motor with exactly enough torque to overcome the friction. This condition was determined by connecting a water manometer across the meter, with the piezometer tubes sufficiently far from the case to avoid errors in the pressure indications due to turbulence. When the water columns in the U-tube balanced, the pressures on the upstream and on the downstream sides of the rotors were assumed to be equal. Sensitive adjustment of the motor speed was afforded by field and armature rheostats.

When rotating with balanced inlet and outlet pressures, the meter should permit no slip but at each revolution should pass a volume of air equal to the displacement of the rotors at the same pressure as that in the inlet and the outlet pipes. Knowing the volume swept by the two rotors and the number of revolutions of the meter, the determination of the volume of air over a given interval is a simple problem in multiplication. The instantaneous flow-rate of air may be measured with a tachometer driven from either the electric motor or the air-meter shaft and graduated in

(*Concluded on p. 326*)

Production Engineering

One of the standards adopted earliest by the Society is the list of taper fittings. This standard was adopted in 1914, and has been in use ever since with little revision and little adverse criticism. Recently there has been some discussion of the methods of dimensioning as shown in the S.A.E. HANDBOOK.[1] To bring this before the members, H. S. Kartcher[2] was asked to contribute a paper on the subject. This is presented herewith.

Mr. Kartcher's paper has been submitted to C. W. Spicer,[3] who was a member of the Miscellaneous Division of the Standards Committee when this standard was originally adopted, in addition to having been a member of the Committee continuously since then. Mr. Spicer says, in connection with the many drawings of taper fittings that come to him, that he believes that 98 per cent of the manufacturers of automobiles and parts either copy the S.A.E. dimensions or briefly state, "S.A.E. taper," giving the large-end diameter. This convinces him that the present method is entirely familiar to and in use by a great majority of the users of taper fittings in the industry.

In regard to dimensioning the taper itself, Mr. Kartcher suggests various methods, depending on circumstances, all of them differing from that shown in the S.A.E. HANDBOOK by expressing the tolerance in terms of the longitudinal position of a basic diameter, rather than by limits on the diameter at the large end of the taper.

It seems that any one of these methods may be used in dimensioning a particular drawing of a part which is to conform to the standardized limits, but it is doubtful whether any one of those suggested could be used universally.

Mr. Kartcher brings out the fact that the sides of the keyway are not parallel to the taper. This is illustrated in Fig. 3. It is a fact that the line of the intersection of the keyway with the taper surface is a section of an hyperbola and not a straight line. The S.A.E. Standard specifies that the keyway shall be parellel to the taper, and shows the dimension for depth of keyway measured from the intersection of the keyway with the conical surface. If the keyway is parallel to the extreme element of the cone at the center of the section removed in cutting the keyway, the depth of the keyway measured at the side will not be constant.

To find what the amount of variation would be, we have computed the dimensions for a few of the standard sizes of taper fitting. Apparently the greatest proportional variation is found in the nominal 1 and 2-in. sizes. In the 2-in. size, dimension a in Fig. 3, measured at the large end of the taper, is 0.0318 in., and dimension b, measured at the small end of the taper in the hub, is 0.0392 in. This makes a variation of 0.0074 in. between the two ends.

Comment from members interested, addressed to the Editorial Department of the Society, in connection with the following questions particularly, will be welcome and appreciated.

(1) Has any trouble been experienced with the methods of dimensioning taper-ends as indicated in the S.A.E. HANDBOOK?
(2) Can you suggest any concrete improvement in regard to these dimensions?
(3) Has any difficulty been found due to uncertainty in regard to keyway depth? Or are the ordinary allowances and tolerances sufficient to prevent trouble?
(4) How, if at all, do you believe that the standard for keyway depth should be revised?

MEASUREMENT OF TAPER FITTINGS

Dimensioning tapers has always been the subject of discussion and varying opinions, with the result that there is a complete lack of standardized practice. In some plants the taper is dimensioned at the large end, in some at the small end, and in some at the middle. Some give diameters at both ends, with a dimension for length between. This has brought confusion in the production, inspection and assembly departments, with consequent expensive arguments and errors. The method of dimensioning the shaft, as given in the S.A.E. HANDBOOK, p. C 14, is shown in Fig. 1. Let us analyze this.

The only way in which the large end of this taper can be measured is by a micrometer applied to the diameter of the shaft. The tolerance given for the 2½-in. size, for instance, is ± 0.002 in. While there generally is no objection to a bilateral tolerance on the diameter of a taper, there is objection in case of a shaft diameter. The S.A.E. HANDBOOK, p. M 21, states: "On mating surfaces, with but few exceptions, the tolerances should be unilateral." We have seen parts of this kind shown with a ± 0.001-in. tolerance immediately behind the taper, and elsewhere on the same shaft a fractional dimension, with ± 0.010-in. tolerance. Frequently this type of taper is used for a rear-wheel shaft with a collar, as shown in Fig. 2. How would the method of dimensioning shown in Fig. 1 apply to this job where there is no cylindrical diameter to measure?

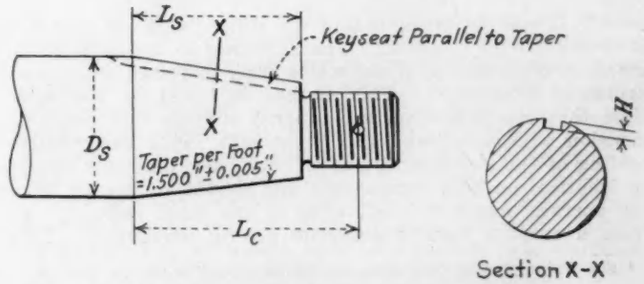


FIG. 1—DIMENSIONING OF A STANDARD TAPER-SHAFT

This Shows a Taper Shaft-End Dimensioned as Shown in the S.A.E. HANDBOOK, p. C14. In the Standardized Tabular Dimensions, Tolerences Are Given for D_s and H. Dimensions Expressed in Fractions Are Given for L_s and L_c

Another objection to the method shown in Fig. 1 is the difficulty of defining the axial location of the tapered seat relative to some other point on the shaft. Dimensions L_s and L_c are examples of this. Anyone who has tried to take a measurement from the line formed by the intersection of a straight diameter and a taper knows how difficult this is to do.

Now let us consider the keyseat which, according to the note on the figure in the S.A.E. HANDBOOK, is parallel to the taper. A sectional view shows the keyseat depth dimensioned from the angle formed by the intersection of the side of the keyseat with the tapered surface of the shaft. Fig. 3 shows

[1] S.A.E. HANDBOOK, p. C14.
[2] Supervisor of shop engineering standards, White Motor Co., Cleveland.
[3] M.S.A.E.—Vice-president and chief engineer, Spicer Mfg. Corporation, South Plainfield, N. J.

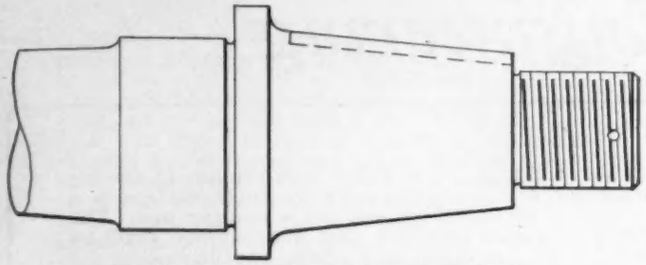


FIG. 2—TAPERED SHAFT-END WITH SHOULDER
When a Shoulder Is Located at the Large End of the Taper on a Shaft, It Is Impossible To Micrometer the Large Diameter

that this angle is not parallel with the taper on account of the variation in diameter.

Dimensioning the tapered hole also presents problems, as shown in Fig. 4. The example shown at the left is comparatively clear; the one in the center leaves uncertainty as to whether the dimension is taken at the face of the hub or at the tangent of the radius; and the one at the right raises doubt as to whether the hub face or the corner of the chamfer is the measuring-point. If the latter, it is necessary to hold the width of chamfer within very close limits. The fact that these questions can and do come up all the time shows that something is lacking.

We have encountered so much of this that we determined to search for a cure. Accordingly, the method shown in Fig. 5 has been approved for use in our plant. It is working very satisfactorily. We do not claim to be the originators of this method; in fact, I used it at the Frankford Arsenal in 1917, and Earle Buckingham illustrates it in his

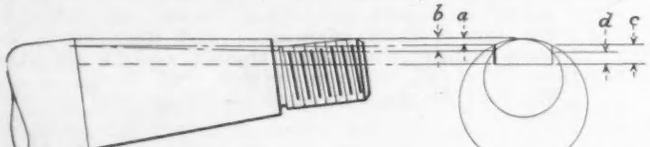


FIG. 3—VARIATION IN DEPTH OF KEYWAY
In This Drawing the Use of an Extra-Wide Keyway Exaggerates the Difference between the Heights of the Arcs *a*, at the Large End, and *b*, at the Small End, of the Taper. With the Keyway Parallel to the Taper, the Resulting Depths Are *c*, at the Large End, and *d*, at the Small End

book.[4] It will be noted that a dimension with no tolerance is shown for the diameter. This is known as the basic diameter and is located by a dimension with tolerance from some pertinent fixed-point. This method is based on the principle that somewhere on the tapered surface this basic dimension will occur, and this point will locate the relative seating of the two mating parts. The basic diameter should be identical on both components and should be located from the surface which is most vital in the final assembly, or from a surface that is available during machining. This

[4] See Principles of Interchangeable Manufacturing, p. 60.

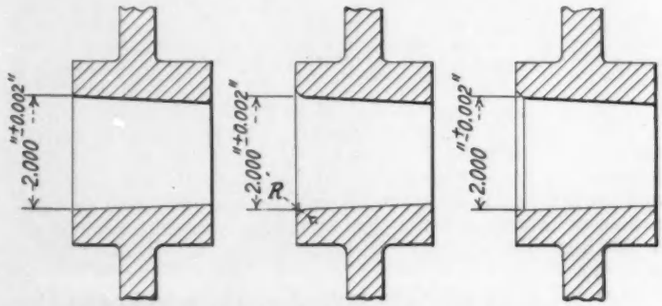


FIG. 4—USUAL METHOD OF DIMENSIONING TAPERED BORES
The Drawing at the Left, Which Shows No Break in the Taper, Is Clear. The Center Drawing, Showing a Radius at the Large End of the Taper, and the Drawing at the Right, Showing a Chamfer at the End of the Taper, Leave Uncertainty as to the Point at Which the Diameter Shall Be Measured

makes it possible to visualize readily the relation between the two parts.

Referring to Fig. 5, we find that the 2.000-in. diameter falls 0.016 to 0.032 in. from the flange on the shaft. This provides a linear tolerance of 0.016 in., which corresponds to a tolerance of 0.002 in. on the diameter. On the hole there is a linear tolerance from flush to 0.016 in. out from the hub face. The extremes of these conditions leave a space of from 0.016 to 0.048 in. between the flange on the shaft and the face of the wheel hub, which gives 0.002 to 0.006 in. interference on the taper after the two parts are drawn together by the nut. The figures given in these illustrations are arbitrary and should not be taken as indicative of rec-

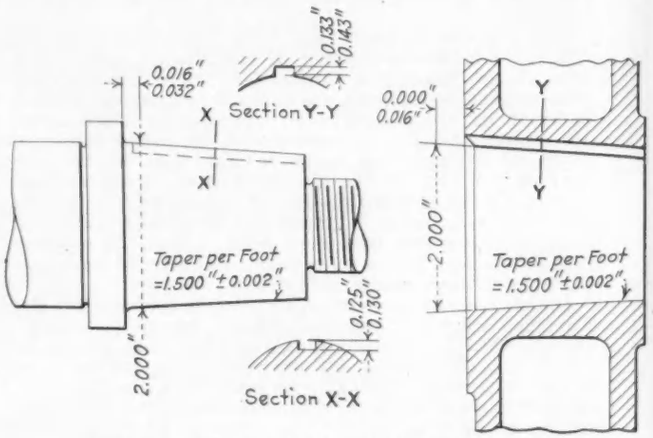


FIG. 5—PROPOSED DIMENSIONING OF TAPER PARTS
It Is Suggested that a Basic Diameter with No Tolerance Be Shown at Some Point of the Taper. The Point Where This Basic Diameter Is Located Is Indicated by a Longitudinal Dimension, with Limits, from Some Suitable Point on the Shaft. The Depth of the Keyway Is Given from the Extreme Element of the Taper, Instead of from the Side of the Keyway

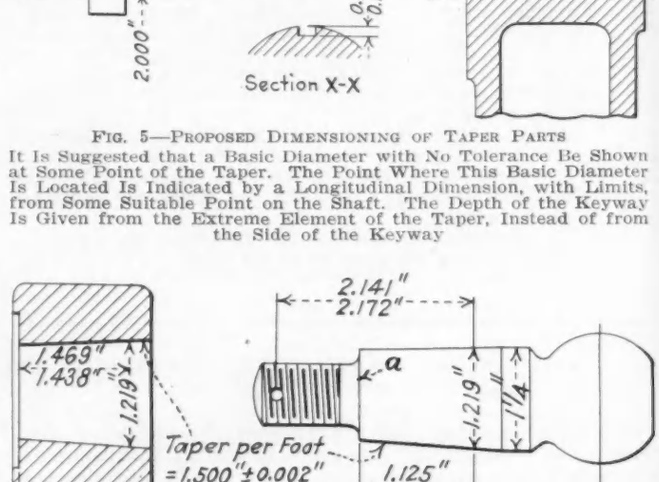


FIG. 6—TAPER DIMENSIONING FROM SMALL END
When the Clearance Is More Important at the Small End of the Taper than Elsewhere, as in This Case, the Basic Diameter May Be Dimensioned from That End. The Cotter-Pin Hole May Be Dimensioned as Shown or from the Shoulder *a*

ommended fits. Each problem requires individual consideration as to that.

The proposed method of dimensioning the depth of the keyseat is shown in Fig. 5. This method will give the machinist all the information he requires. Likewise, in broaching the keyway in the hole, the slot in the broaching adapter will be made parallel to the taper and will naturally produce the keyway in a similar position.

Fig. 6 illustrates a case in which we are especially interested in the space left between the shoulder on the small end of the stud and the nut or washer face. The cotter-pin hole may be located either from the basic diameter as shown or from the shoulder *a*, depending upon the sequence of machining operations.

When parts are to be assembled in definite relation without being pulled up hard against a shoulder, an assembled drawing must be provided to show the required position.

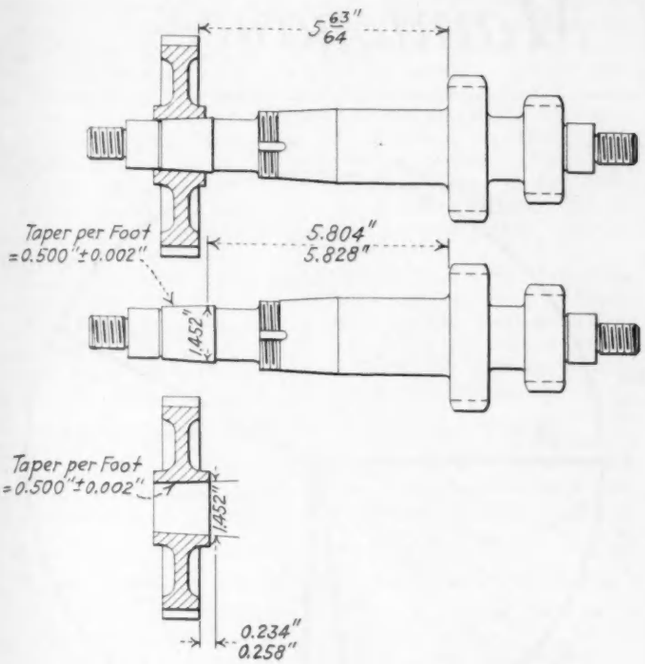


FIG. 7—POSITIONING WITHOUT A SHOULDER

The Dimension 5 63/64 In., in the Upper Drawing, Shows the Position in Which the Gear Must Be Assembled on the Taper Portion of the Shaft. The Middle Drawing Shows the Shaft, and the Lower Drawing Shows the Gear, with the Same Basic Diameter for the Taper Located from a Suitable Point on Each

Such a case is shown in Fig. 7, where the basic diameter for the bore is located from the flange of the gear, and the basic diameter for the shaft is located from the gear that is integral with it. Adding the two minimum limits, 5.804 + 0.234 in., and the two maximum limits, 5.828 + 0.258 in., we find that the flanged gear will be located 6.038 to 6.086 in. from the gear that is integral with the shaft when the two parts seat without pressure. Comparing these figures with the 5 63/64 (5.984) in. in the assembled view, we find that there will be a "draw" of 0.054 to 0.102 in., equivalent to 0.0023 to 0.0043 in. interference in diameter, when the parts are pressed together as shown in the assembled view.

Gages used in the production of tapered parts that are dimensioned in accordance with the proposed method are shown in an article entitled Accurate Gaging of Tapers, by A. J. Cayouette.[5] This article describes thoroughly the inspection of tapers and the master gages used for this work. —*H. S. Kartcher.*

A FACTOR IN NATIONAL PROSPERITY

Production Engineer's Broader Vision Makes Possible New Era in Industry

Integrated production, the subject that E. P. Blanchard, of the Bullard Machine Tool Co., will discuss at the Production Meeting in Cleveland on the evening of Sept. 19, will make a wide appeal to all men who are interested in automotive production. Because of the keen interest that has been evinced in this paper, a brief outline is given here for those members who desire advance information in regard to the way in which this topic will be developed at the Production Meeting this month.

The present, says Mr. Blanchard in his paper, is a new era of production made possible by the broader vision of the production engineer, manifesting itself in the development of the production man from stock-chasing through coordinating performance, his interest in mechanical means and his present interest in economy and the financial features of his job.

[5]See *Machinery*, August, 1926, p. 945.

Present production has settled down on a basis of profit per unit. Every stage in quantity production justifies more refinement. The whole job for any production engineer is split into component units of manufacture. Units are divided into parts and parts into the operations required on each, in accordance with the new idea of splitting operations so far as practicable to obtain balance in time of performance and then multiplying performance. There is a point which provides greatest economy for the particular quantity required in any case. Beyond this peak of economy is a period of diminishing returns.

Any piece of work divided into operations can be figured down to the tool time; that is, the time per tool required to accomplish each operation. Then comes the accumulated tool-time, the putting together in balanced ratio of all operations with provisions for mechanical rates of production. This is balanced performance, a building up of the process from the original exact mechanical requirements. It is integrated production. Integrated production is really a new principle which becomes evident in automotive production practice but on further study is found to be present in all production processes.

DESIGN ADAPTED TO AVAILABLE EQUIPMENT

Adapting the design of mechanical parts of a car to the equipment available for their production brings a closer relation between design and the production engineer, accomplishing several minor savings in almost every case, and in some cases avoiding the necessity for purchasing expensive equipment. Production engineers have learned (*a*) to balance equipment to accomplish the operations in the shortest possible time; (*b*) to specify refinement of equipment to meet the production conditions in quantity; and (*c*) to make a distinct saving at every point possible throughout the whole manufacturing process. This really means establishing a common multiple of all of the factors in production that will render the greatest profit on the basis established by manufacturing practice and the conditions in the specific shop.

A great saving to the industry is undoubtedly the result. From the financial point of view, such economy as production engineers have been able to accomplish may be playing an extremely important part in the present enviable financial situation of the United States. The conditions of prosperity and ready money have been contributed to, to no small extent, by the savings made by machinery and by the men who use it. Aside from the direct and indirect labor saving, there is the quicker turnover in the manufacturing process, reduction of the material inventory, a smaller amount of work-in-process, and greater flexibility in the process, which avoids over-production. These result in not only a shorter financing period in smaller amounts, but in elimination of waste in the finance required.

Such savings on a National scale cannot help but contribute millions to the favorable balance situation that now exists. It may be a new point of view but it is worthwhile for the production engineer to look beyond the problems in his own shop and realize how much he has contributed, as a factor in manufacturing, even to such an ultimate phenomenon as the present National prosperity. Tracing our present prosperity to the original causes, the production engineer, probably more than any other, is the major source.

WHAT INTERESTS PRODUCTION MEN?

Production-Meeting Subcommittee Arranges Program Based on Answer to This Question

Every production man will find something to merit his careful attention in the program for the Society's Production Meeting that will be held at the Hotel Winton, Cleveland, Sept. 19 and 20, and at the Hotel Statler, Detroit, Sept. 21 and 22. A more detailed announcement of the interesting features of the program, comprising six well-balanced technical sessions and the Stag Carnival, will be found in this issue on p. 217.

Operation and Maintenance

COST PROBLEMS OF MOTOR CARRIERS

Must Know Unit Costs and How They Vary—Inexpensive Uniform System Needed

Elements making up the total cost of transportation are many and varied. Some are fixed regardless of increase of service; some vary directly with the volume of business or with a given unit of service. Upon the correct basis for assigning costs and finding out with what they may vary depends the profitableness of an enterprise, particularly in dull times when every fraction of a cent must be made to count.

The motor-carrier business today is not radically different, at its age, from any other transportation business, but our other transportation systems are now so established that they have rather generally forgotten their early troubles. These troubles are mainly the unknown life of units and the obsolescence of types of equipment due to improvements in the art. These factors were provided for in the early days by high rates and charges and by obsolescence funds that were reduced gradually as unit life became known and equipment was standardized. Motor carriers enter the field without this knowledge as to their industry and in direct competition with the reduced rates of standardized transportation; hence the life and obsolescence problem must be solved within this reduced-rate structure.

Depreciation an Unknown Quantity

Depreciation is still an unknown quantity. Unless obsolescence overtakes us, many stages or motorcoaches continue to run and are in good operating condition long after we have ceased to charge off depreciation. Obsolescence, due to change in body types as the result of constant advance in luxuriousness and style, has been a serious factor. In a transportation system that has several kinds of service, it is possible to decrease this obsolescence loss by building for high-class intercity lines the most modern equipment and relegating that displaced to the lesser or back-country lines; but if the carrier has no place on his own lines to use displaced equipment, little better than scrap value can be obtained for it. The ratios between investment, gross revenue and operating expenses are so different that increases in operating expenses throw the business into panic.

A 20-per cent increase in operating expense on a railroad would be only 2 per cent on the investment. With the motor carrier, this increase would be 18 per cent on the investment; the 20 per cent, of course, is exaggerated, but it illustrates that any reasonable increase in operating expenses, while not felt by a railroad, almost immediately shows red ink with a motor carrier. A decrease is, naturally, to the advantage of the motor carrier but, because of the way prices have fluctuated during the last 4 years, nearly all motor-carriers' books show black and red fluctuations that resemble fever charts.

It is more necessary, therefore, that we know ourselves than for other forms of transportation to know themselves. When we know, which we do not now, what our unit costs should be, and how and why they vary, we can cut or expand as required, and do it when needed, instead of feeling our way slowly and injuring service by our lack of knowledge of where to reduce with the least harm.

I have not touched on that abomination, assumed average-cost distribution, advocated by many accountants. How can anyone keep in touch with actualities who charges off tires or gasoline or maintenance at so much per mile? To be sure, one can make a nice uniform monthly statement of operating costs in this manner, but it is so far from reflecting operating conditions that the management relying on it is likely to be drowned without knowing it.

Our company is using a uniform classification adopted by the Railroad Commission of California, similar to that authorized by the Interstate Commerce Commission for steam and electric railways, but has subdivided the prescribed accounts to meet its needs. The four general accounts of this classification are distributed approximately according to the percentages around the circumference of the circle in Fig. 1.

These general accounts are divided into primary accounts as shown by Fig. 1 and Table 1. The primary accounts are fixed charges to the extent of about 52 per cent, while 48

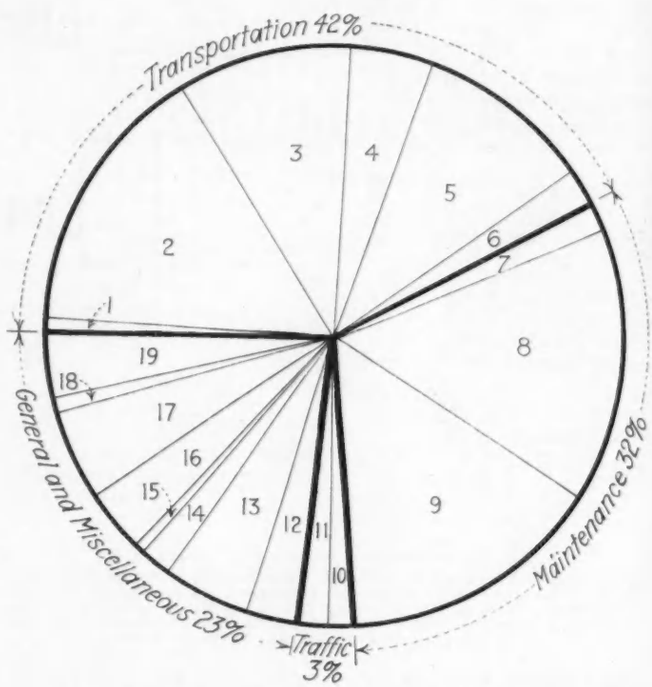


Fig. 1—Division of Four General Accounts into Primary Accounts

Percentage That Each General Group Bears to Total Expense Is Shown Outside of the Circle. Figures within the Circle Refer to Primary Accounts within Each General Group as Listed in Table 1

This article, by Franklin D. Howell,[1] which is based upon a paper presented by him before the Los Angeles Chapter of the National Association of Cost Accountants, is remarkable for two reasons: First, because of the concrete figures and proportions given, which show the positive necessity for continuous and careful analysis of financial records by all motor-carrier managers; and, second, for the author's observations on the policies and practices of management. These observations are the fruit of long experience and sound thinking. They deserve most careful consideration.

[1] M.S.A.E.—Vice-president and general manager, Motor Transit Co., Los Angeles; vice-chairman, Operation and Maintenance Committee of the Society.

per cent varies directly with the mileage operated. Every mile operated should carry its proper share of overhead or fixed charges, although this is not always necessary or possible, if the actual point can be found where a vehicle can be operated on a revenue that covers out-of-pocket cost. This would increase gross revenue and operating expense. Operating revenue would not be increased, but the public would receive added service without loss to the carrier. All properly organized effort can take on perhaps 10 per cent additional service without increasing the overhead; but a reduction in service down to about 10 per cent seldom permits reduction of overhead.

We cannot stop there; some schedules are so lean that they produce even less than the out-of-pocket cost. If these are cut off arbitrarily, the revenues on the good schedules are likely to be reduced. The individual patron who is forced to find other means of transportation at the time he desires to travel is followed by his family and his friends.

Fluctuating Material and Supply Prices

As to the other variables with which we have to contend: Working on a margin of 2 cents per motorcoach-mile or less, the fluctuation on prices of materials and supplies is serious and may mean the difference between profit and loss. Variations in actual cost to us of tires and fuel for the years 1923 to 1926 are shown by Table 2. Tires, comprising both casings and tubes, vary from 1.62 to 3.00 cents per motorcoach-mile; and the cost of gasoline from 1.86 to 3.07 cents per mile. These figures are based on eight tires, including two spares, for each motorcoach or stage, and on a gasoline consumption of 1 gal. to 7 miles. Prices of other materials change in much the same way.

In managing a system with all the variables I have outlined, the problem is not so much the procedure and forms that will give all the data needed, but rather to secure the information without excessive cost. We have developed forms and a procedure of our own, but their use is expensive. They must be devised so that any employe, whether greaser, mechanic, gasoline-man, or car-wiper, can understand and handle his part of the work. The information originates with these men and upon its accuracy depend the results of the analysis made later in the general office.

TABLE 1—DIVISION OF OPERATING EXPENSES BY PRIMARY ACCOUNTS

Chart Reference No.		Relation to Total Expense, Per Cent	Type[2]	Relation to Group Expense, Per Cent
	Conducting Transportation			
(1)	Superintendents' salaries and expense	0.84	FC	
(2)	Operators' wages	15.60	VM	37
(3)	Gasoline, oil and supplies	9.66	VM	
(4)	Service cars and garage expense	4.62	FC	
(5)	Station salaries and expense	9.66	FC	23
(6)	Miscellaneous, sundry	1.68		
	Total Transportation	42.06		
	Maintenance			
(7)	Buildings, machinery and tools	0.32	FC	
(8)	Equipment, tires and tubes	19.52	VM	
(9)	Depreciation	12.16	FC	
	Total Maintenance,	32.00		
	Traffic			
(10)	Soliciting, advertising and miscellaneous	1.26	FC	
(11)	Advertising	1.74	FC	
	Total Traffic	3.00		
	General and Miscellaneous			
(12)	General office and expense	2.76	FC	12
(13)	General officers' salaries and expense	5.06	FC	22
(14)	Stock-room, salaries and expense	1.61	FC	7
(15)	Insurance, miscellaneous	0.46	FC	2
(16)	Insurance, liability and property damage	3.68	VM	16
(17)	Taxes	5.06	FC	22
(18)	Legal	0.92	FC	4
(19)	Miscellaneous	3.45	FC	15
	Total General and Miscellaneous	23.00		100

[2] FC = Fixed charges. VM = Varies with motorcoach mileage.

TABLE 2—RANGE OF TIRE AND FUEL PRICES BY YEARS

Year		36 x 6-In. High-Pressure Tires Casings	Tubes	per Gallon, Gasoline, Cents
1923	High	$74.65	$10.00	20.0
	Low	56.85	7.60	13.0
Variation, Per Cent		31	32	54.0
1924	High	56.85	7.60	19.0
	Low	48.30	6.30	16.5
Variation, Per Cent		18	21	15.0
1925	High	88.75	12.10	18.5
	Low	48.30	6.30	16.5
Variation, Per Cent		84	92	11.0
1926	High	88.75	12.10	21.5
	Low	56.00	7.40	16.5
Variation, Per Cent		59	64	30.0
1927	High	..	..	19.5[a]
	Low	..	..	10.0[a]

[a] For 6 months.

In managing a system with all the variables I have outlined, the problem is not so much the procedure and forms that will give all the data needed, but rather to secure the information without excessive cost. We have developed forms and a procedure of our own, but their use is expensive. They must be devised so that any employe, whether greaser, mechanic, gasoline-man, or car-wiper, can understand and handle his part of the work. The information originates with these men and upon its accuracy depend the results of the analysis made later in the general office.

Standard Unit-Costs and Classification Needed

All motor carriers should keep unit costs in the same way, following the same method and using the same classification so that we could, by comparison one with the other, stop our leaks. This we cannot do today, for all, even the larger companies, keep records on some home-devised basis, each emphasizing different factors. We have arrived at the second period only of our "costing." In the first period, when the motor-carrier business started, if we had any money in pocket when the day's work was over, it was regarded as profit. The period we are now entering will be that of properly distributing all accounts and producing statistics that will permit of correct deductions and comparisons with the operations of others.

RAILROADS AND MOTOR-VEHICLES

Motor-Trucks and Motorcoaches Are Rapidly Supplementing Steam Transportation

The ultimate relationship between the railroad and the motor-truck and motorcoach is the objective of a study conducted by the Interstate Commerce Commission, which recently issued statistical summaries that show, beyond all doubt, the importance of motor transportation in the social and economic life of the Country.

Hearings were held in various parts of the Country and all common carriers subject to the Interstate Commerce Act were made respondents to the proceedings and were required to furnish to the Commission so far as possible all vital information regarding motor transportation.

At present, according to the Interstate Commerce Commission, the motorcoach mileage has surpassed that of the Nation's steam railroads. There are now in operation as com-

mon carriers more than 22,000 motorcoaches in line and terminal service, covering a route-mileage of more than 352,000 miles. In addition, the Commission found that more than 45,000 motor-trucks are being operated in line and terminal service for the exclusive transportation of goods. The route-mileage covered by these trucks was approximately 612,000 miles.

As compared with the century-old development of the railroads, motor service is still a new factor in the Nation's transportation system. What does such a whirlwind growth mean, and how will further expansion, which is inevitable, affect our modern civilization?

No Conflict of Agencies

The bugaboo of rail and motor conflicting interests is fading away; there is no real conflict between these great carrying agencies. As a matter of fact, they naturally are supplementary to each other. The railroads are using the motorcoach and motor-truck more and more as feeders where their charters permit their adaptation to new conditions. The movement toward railroad consolidation is bound to influence the motorcoach and motor-truck companies and to lead to further coordination of the several transportation agencies.

The railroads generally are not now opposed to the motorcoach and motor-truck. An increasing number of the carriers are using them, because it has been shown that the motorcoach lends itself to use as an auxiliary. It penetrates sections lacking transportation facilities and brings additional business to the main line. The railroads and the motorcoach and motor-truck interests are working for the same goal; they are looking forward to the time when properly coordinated rail and highway common-carriers will serve the public most economically, efficiently and conveniently.

TERMINAL FREIGHT-SERVICE

Motor-Trucks a Valuable Factor in Handling Merchandise at Railroad Terminals

Handling freight within railroad terminals by motor-truck is reducing the high cost of such traffic, particularly through congested districts. The time required to handle intra-terminal movement with motorized operation as compared with railroad operation has been reduced from 24 to 72 hr.

Compared with other railroad uses of motor-vehicles, motor-truck operation in terminals has been existent for a long time; many roads have used them for years. It is only within the last year or two, however, that there has been a really rapid development in this direction. This development appears to indicate that the use of motor-trucks, tractors and trailers for the transportation of freight at congested terminals will at no distant date become the usual thing among railroads generally.

Another phase of the situation that has been investigated recently is referred to as follows in a recent report of the Commerce and Marine Commission of the Executive Council of the American Bankers' Association dealing with the increase in the automobile business and comparing that industry with the railroads of the Nation.

> In competition with railroads, the effect of the motor-truck is relatively light. The total ton-miles produced by trucks last year in competition with railroads is estimated at 8,000,000,000, or about 2.1 per cent of the railroad total of 488,000,000,000. Tonnage lost by railroads to motor-trucks was relatively small and of a kind the railroads have found least remunerative. The loss is more than equalled by the large volume of railroad-carried automotive freight.
>
> The motor-truck meets a real public need in providing quick, flexible service for distances of from 30 to 60 miles. It is in the interest of the railroads as well as the public to acquiesce in the diversion of that traffic to the highway so that railroad facilities may more profitably be used for long-haul traffic. This traffic is growing in volume and the gain is much greater than the loss of less-than-carload freight to trucks. The use of motors on light-traffic branch-lines is increasing and an extensive development in that field is probable.
>
> To offset their losses the railroads are going extensively into motorcoach operations themselves as supplements to or substitutes for trains on light-traffic branch-lines. Railroad activities in the motorcoach field are likely to be extended. The motorcoach, railroad operated, offers a promising solution of the problem of abandoning unprofitable lines without inconvenience to the public.

MOTORCOACH IMPROVEMENTS

Suggested at Service-Managers' Forum of Automobile Chamber of Commerce

Several topics suggested at a recent forum of the National Automobile Chamber of Commerce in Cleveland had already been considered by the Operation and Maintenance Committee of the Society, and definite plans had been made for a careful study of them for the purpose of drafting recommendations. Probably the most important subject that has thus come under consideration is formulating reliable check-test specifications for use in purchasing lubricating-oils and fuels, especially by motor-vehicle operators who buy in tank-car quantities. This study is now before the Research Committee as a result of discussion at the Summer Meeting of the Society.

The important preventive of rapid wear that is directly under the vehicle owner's control but that is seldom given the consideration to which it is entitled is the use of lubricating-oil and fuel of high quality that are free from foreign matter and from corrosives and acids that are prevalent in cheaper products. Progressive oil companies maintain a staff of experienced chemical engineers whose entire time is devoted to study, not only of the prevailing design and construction of gasoline-propelled equipment, but of the demands made upon them by users. These men must of necessity keep pace with every change, study every class of oil and fuel and anticipate the trend of the times. If these large organizations realize the futility of following any other course, it is a foregone conclusion that the owners of motor-vehicle equipment must give the subject due consideration or be satisfied to have their units working under adverse conditions.

Regarding gasoline tanks, an important factor that would at least have a bearing is the regulation of public-carrier vehicles in some of the States. This phase of the matter will be taken up by the Operation and Maintenance Committee's Subcommittee on Motor-Vehicle Regulations.

The problems of brakes and tires are closely related, particularly in connection with motorcoach design, because of the restricted available space affecting the design of both elements and the effect on tires of the heat absorbed by them from the brake mechanism.

Some Mechanical Features of Suspension Leaf-Springs

By Tore Franzen[1], S. P. Hess[2] and Clark A. Tea[3]

Detroit Section Paper *Illustrated with* Photographs and Charts

The paper contributes additional scientific knowledge regarding leaf springs and is in some respects a continuation of the paper on Automobile Riding-Comfort[4], by S. P. Hess. Special emphasis is given to some of the principles that underlie design and to the dynamic behavior of springs with particular reference to interleaf friction.

THE principal stresses in a leaf spring are those caused by bending. They are transverse, and are usually determined by calculation; but they can also be measured accurately by the recently developed strain-gage shown in the central view of Fig. 1. The two points *A* and *B*, shown in the lower portion of this view, are held against the surface under investigation. As the skin of the metal is elongated or shortened, the movable point *A* of the instrument actuates a dial indicator, *C*, through a mechanism having a ratio of 300 to 1. Each graduation on the dial corresponds to a stress of 4000 lb. per sq. in. An application of the strain-gage is given in detail in the view at the left in Fig. 1. The dial is read with the aid of a mirror held under the instrument when main-plate stresses are investigated. At the right in Fig. 1 is a general view of a conventional testing-machine with a spring in position and two strain-gages attached.

Inasmuch as stresses constitute one of the principal factors to be considered in spring design, the fundamental theory of simple leaf-springs having a rectangular cross-section is reviewed herewith. A spring having maximum efficiency is one in which the stresses are distributed uniformly. A diagrammatic design giving this result is shown in the central view of Fig. 2. In contrast, a spring of uniform section having the same deflection under the same load is shown in the view at the left, in which the elastic curve is that of a parabola; in the central view it is that of a circle. The stresses are uniformly distributed in the spring shown in the central view, but a decided maximum stress is reached at the center of the spring shown in the diagram at the left.

The proportion of weight of the spring shown in the central view of Fig. 2 as compared with that of the spring in the diagram at the left is 100 to 131. This is true when the load, deflection and length are the same, but with no regard given to equalization of stresses. If the stresses are equalized and the remaining provisions also are made, the weight proportion becomes more decidedly in favor of the spring shown in the central view

[1] M.S.A.E.—Assistant chief engineer, chassis spring division, Detroit Steel Products Co., Detroit.
[2] M.S.A.E.—Chief engineer, spring department, Detroit Steel Products Co., Detroit.
[3] Research engineer, chassis spring division, Detroit Steel Products Co., Detroit.
[4] See The Journal, July, 1924, p. 82.

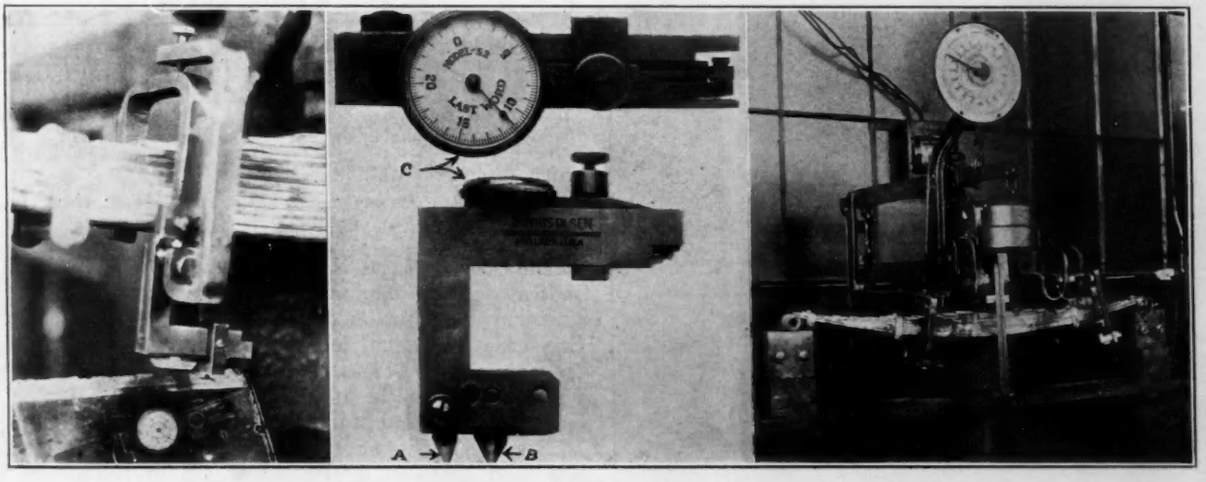


Fig. 1—Recently Developed Strain-Gage

The Two Points *A* and *B* Shown in the Central View Are Held Against the Surface under Investigation. As the Skin of the Metal Is Elongated or Shortened, the Movable Point *A* of the Instrument Actuates the Dial Indicator *C*. The Dial Is Read by the Aid of a Mirror Held Underneath the Instrument When Main-Plate Stresses Are Investigated. An Application of the Strain-Gage Is Shown in Detail in the View at the Left. At the Right Is a General View of a Conventional Testing-Machine with a Spring in Position and Two Strain-Gages Attached

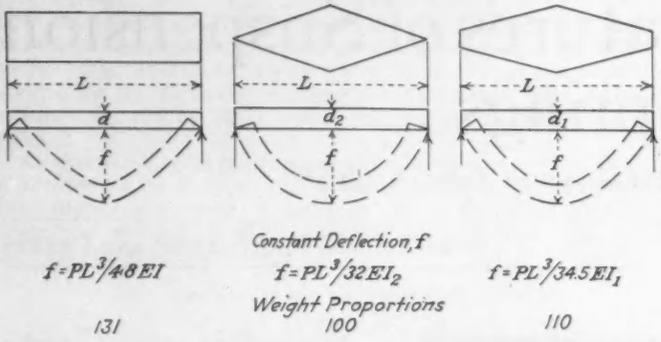


FIG. 2—THEORY OF SIMPLE LEAF-SPRINGS HAVING A RECTANGULAR CROSS-SECTION

The Central View Shows a Uniform-Strength Beam, the View at the Left a Beam of Non-Uniform Strength and the View at the Right a Beam of Modified Uniform Strength. In the Central View, the Elastic Curve Is That of a Circle; in the View at the Left, It Is That of a Parabola. The Stresses Are Uniformly Distributed in the Spring Shown in the Central View, but a Decided Maximum Stress Is Reached at the Center of the Spring Shown in the Diagram at the Left. To Provide for Sufficient Resistance for the End-Shear to Which Leaf Springs Used in Automobile Suspension Are Subjected, It Is Necessary To Make the Design of the Conventional Suspension-Spring Lie between the Extremes Indicated in the Central and Left Views. A Representative Spring of This Type Is Shown Diagrammatically in the View at the Right

of Fig. 2. To provide for sufficient resistance for the end-shear to which leaf springs used in automobile suspensions are subjected, it is necessary to make the design of the conventional suspension-spring lie between the extremes indicated in the central and left views of Fig. 2. A representative spring of this type is shown diagrammatically at the right in Fig. 2. Here the elastic curve is intermediate and lies between those in the central and left views, the weight of the spring at the right being only 10 per cent more than that of the spring of maximum efficiency shown in the central view.

Six distinctly different spring-designs were followed in making up the six springs shown in Fig. 3. These are lettered *D*, *E*, *F*, *G*, *H*, and *I* and are studied individually in the charts shown in Figs. 4 to 9 inclusive.

Spring *D* of Fig. 3 can be considered a rather common design. The main plate is heavier than the other plates and the steps are all alike from the edge of the seat, which is 4 in. long. In the study of spring *D* shown in Fig. 4, the shaded area indicates the amount of steel in excess of that required in a uniformly stressed spring where the length of each leaf bears a direct relation to the moment of inertia of the laminations used. In Fig. 4, as in Figs. 5 to 9, the stresses were determined for 2, 4, 6 and 8-in. deflections at points 2 in. apart along the main plate. Spring *D* is a splendid example of poor stress-distribution. It will be noticed that when the stresses are approximately 120,000 lb. per sq. in. at the center, they are only one-half that amount 4 in. from the eye. The lower portion of Fig. 4 shows the "negative" stresses in the main plate caused by assembly nip or pull between plates. In this particular case, which is a fair average for the rear spring of a small passenger-car, the maximum assembly-nip stress is 10,000 lb. per sq. in. near the center, diminishing gradually to zero at approximately 16 in. from the point of maximum stress.

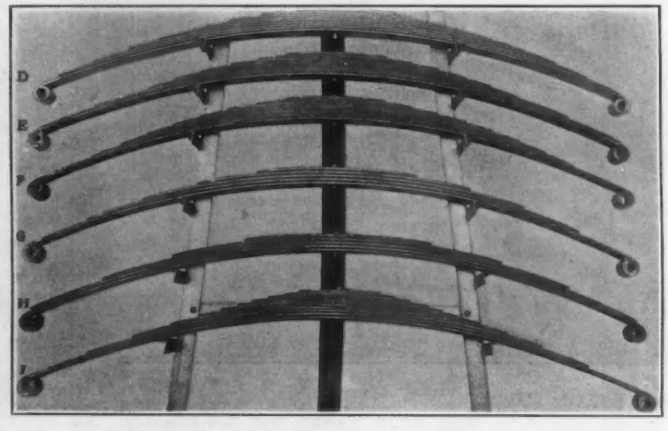


FIG. 3—DIFFERENT SPRING-DESIGNS ILLUSTRATED

Six Distinctly Different Designs Were Followed in Making Up the Springs *D* to *I* Inclusive and Illustrations of Studies Made of These Springs Individually Appear in the Charts Shown in Figs. 4 to 9

Fig. 5 shows a study of spring *E*, of exactly the same grading as that in Fig. 4. The plates have been proportioned to the moment of inertia of each leaf, except

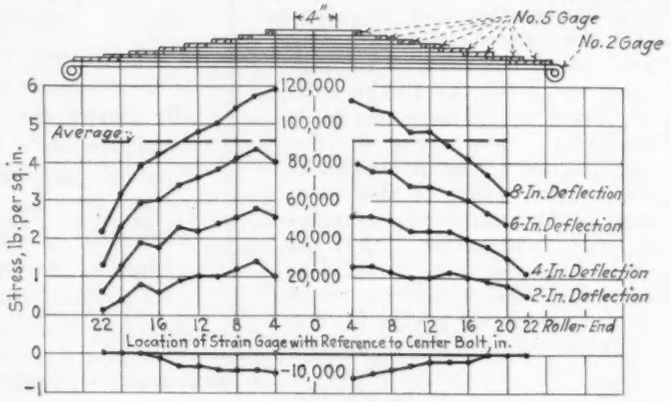


FIG. 4—STUDY OF SPRING *D* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line. No Lubrication Was Used

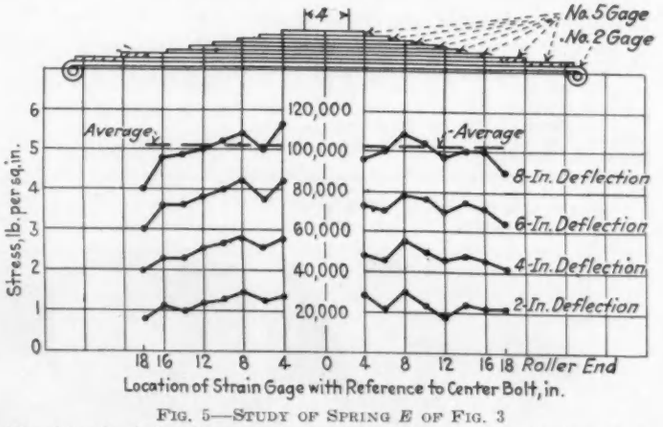


FIG. 5—STUDY OF SPRING *E* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line

in the case of plates Nos. 2 and 3, where the shaded area indicates more steel added than that necessary to give uniform distribution of material. The stress curves in this case are equalized considerably and the variation from maximum is less than one-half of that illustrated in Fig. 4. Fig. 6 is a study of spring *F*, of the same leaf-thickness and number of plates as that of spring *D*, Fig. 4. In this case the moment of inertia of each leaf has been followed in the laying out of the entire plate-diagram. This particular spring has little commercial value and is shown merely as a comparative design, indicating how little difference there really is between it and the design of spring shown in Fig. 5.

Fig. 7 is a study of spring *G*, of practically the same

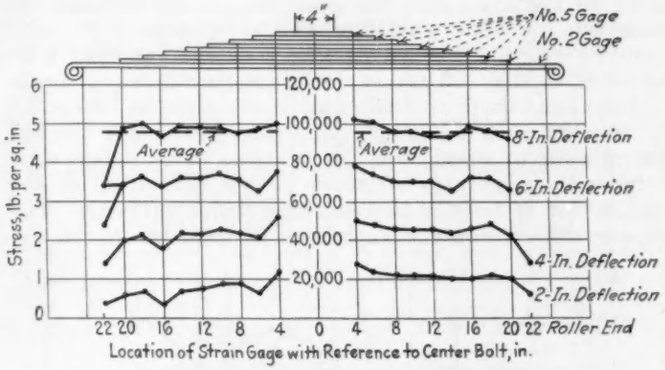


FIG. 6—STUDY OF SPRING *F* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line

properties as those of the study illustrated in Fig. 6. It is composed of fewer plates, and all the plates are of the same thickness. This spring is parallel in design to that of Fig. 6, inasmuch as the stepping of the leaves is made directly in proportion to the moment of inertia of each plate. Fig. 8 shows spring *H*, parallel in design to spring *D*, Fig. 4, but having the same number of plates and the same thicknesses of leaf as has spring *G*, illustrated in Fig. 7. Spring *I*, illustrated in Fig. 9, is stepped

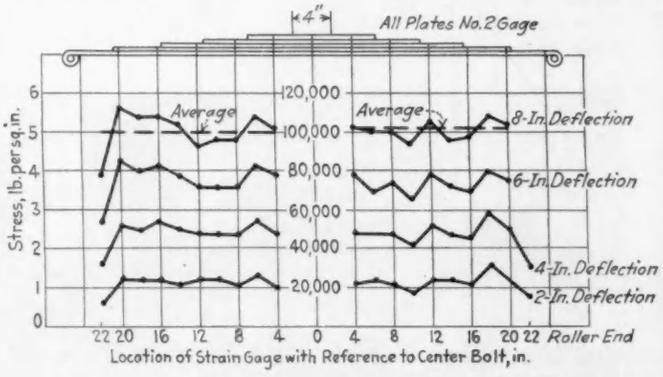


FIG. 7—STUDY OF SPRING *G* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line

directly according to the moment of inertia of each plate. The six longer plates are of different gages, from No. 2 to No. 7 inclusive, and, with the conventional amount of nip, this spring would have practically uniform stress throughout; it is a design laid out for test purposes only and is of no direct practical importance. Such a spring would need to be modified to the same extent as that illustrated in Fig. 5, and the different stresses between the closely adjacent gages is too small to warrant such detail.

From the data obtained in several tests of the nature of those shown in Figs. 5 to 9, the conclusion is drawn that it is desirable to design leaf springs so that the stepping of the plates is proportional to the moment of inertia of the laminations, except for the necessary strengthening near the eyes to take care of rebound conditions and, perhaps, in some cases, merely to provide a conventional appearance. It is possible to conceive applications in which a spring is not subjected to rebound reactions and in which torque and drive reactions are taken through other mechanical members of the motor-vehicle.

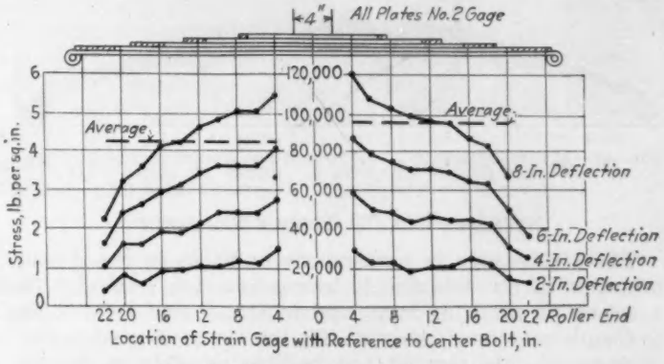


FIG. 8—STUDY OF SPRING *H* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line

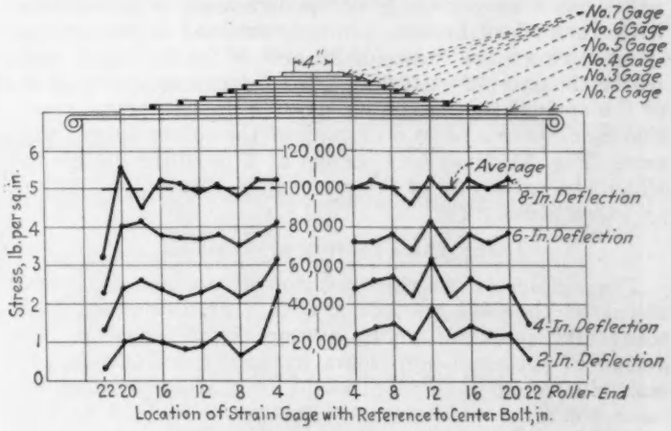


FIG. 9—STUDY OF SPRING *I* OF FIG. 3

The Trend of the Stresses in the Main Leaf of the Spring under 2, 4, 6, and 8-In. Deflection Is Shown, the Average Being Indicated by the Dotted Line

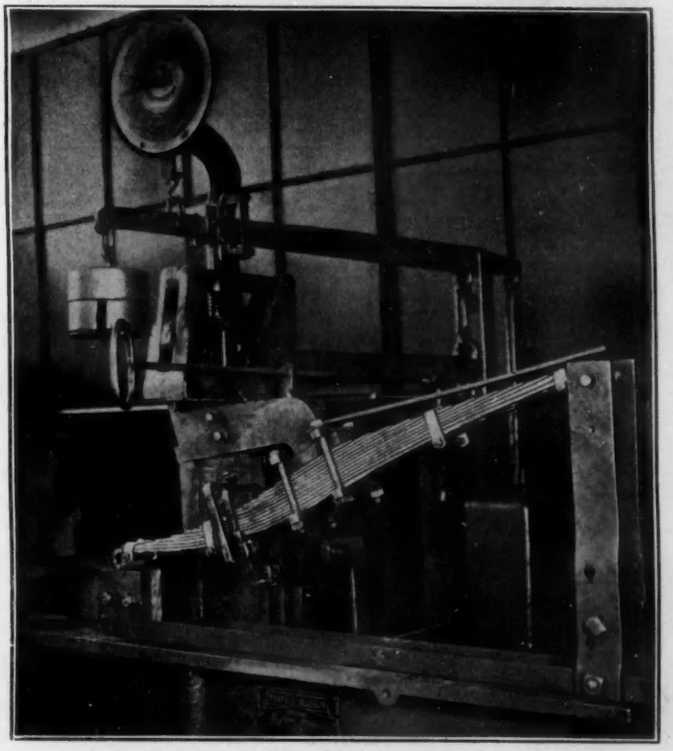


FIG. 10—SET-UP OF A SPRING SUBJECTED TO STATIC LOAD AND TO TORQUE REACTION

By the Aid of Data Obtained in Tests of This Sort, It Is Possible To Design Springs That Will Resist Torque Effectively

FIG. 11—MODIFIED DESIGN OF A SPRING IN WHICH STRENGTHENING OF THE REAR END IS EFFECTED BY ADDING AN EXTRA PLATE

STRESSES DUE TO TORQUE REACTION

The strain-gage is particularly valuable in the determination of stresses due to torque reaction. In Fig. 10 a set-up of a spring subjected to static load as well as to torque reaction is shown. By the aid of data obtained in tests of this sort, it has become possible to design springs that will resist torque effectively. Such provision is seldom necessary on rear springs, but it is comparatively common on front springs used in connection with four-wheel brakes. In conventional front-springs lying between the limits of 36 and 40 in. in length and where the axle offset is 1 to 1½ in. from the center line of the spring, the maximum stresses due to torque reaction lie close to a point 8 in. back of the center line of the axle. Fig. 11 gives an example of a modified design in which strengthening of the rear end is effected by adding an extra plate.

INTERLEAF FRICTION OF SPRINGS

The subject of interleaf friction of springs has been discussed considerably and a wide variation of opinion concerning it exists among engineers interested in the design of springs. For years we have been advocating multiple-leaf springs as a means of spring damping in cases where no one device for this purpose could be applied. To prove our contention, we laid out the following research program.

Friction is the resistance to motion of one surface against another and varies within wide limits according to the kind and the condition of the surfaces in contact. A wide variation exists between static and sliding friction. When dealing with the interleaf friction of springs, all the surfaces are considered as being of steel and their condition can be described as "smooth."

Fig. 12 shows a simple laboratory-device for the determining of coefficients of friction. The upper view shows the apparatus adjusted for the derivation of the coefficient of friction between two simple surfaces. The lower view shows the apparatus as adjusted for determining the friction between eight simple surfaces, or four "common" surfaces. The term "surfaces" referred to hereinafter will be taken to mean "common" surfaces unless stated otherwise.

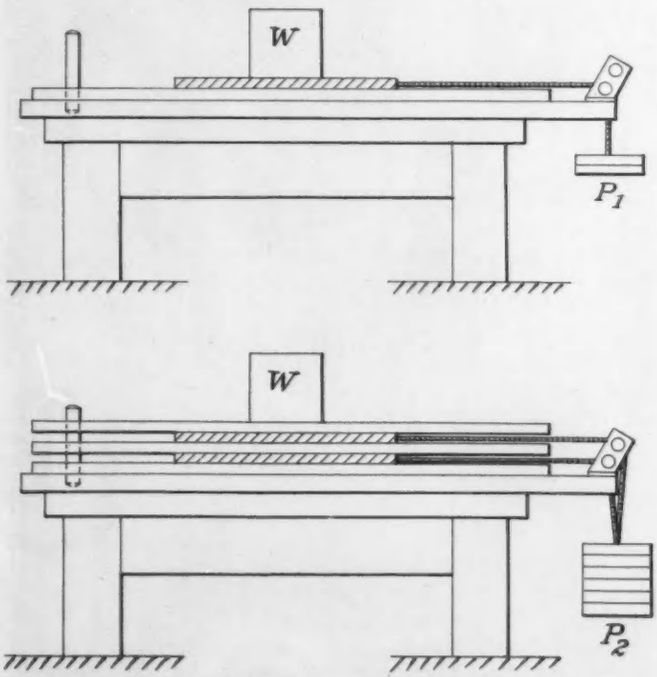


FIG. 12—SIMPLE LABORATORY-DEVICE FOR DETERMINING COEFFICIENTS OF FRICTION

The Upper View Shows the Apparatus Adjusted for the Determination of the Coefficient of Friction between Two Simple Surfaces. In the Lower View the Apparatus Is Shown for Determining the Friction between Eight Simple or Four "Common" Surfaces

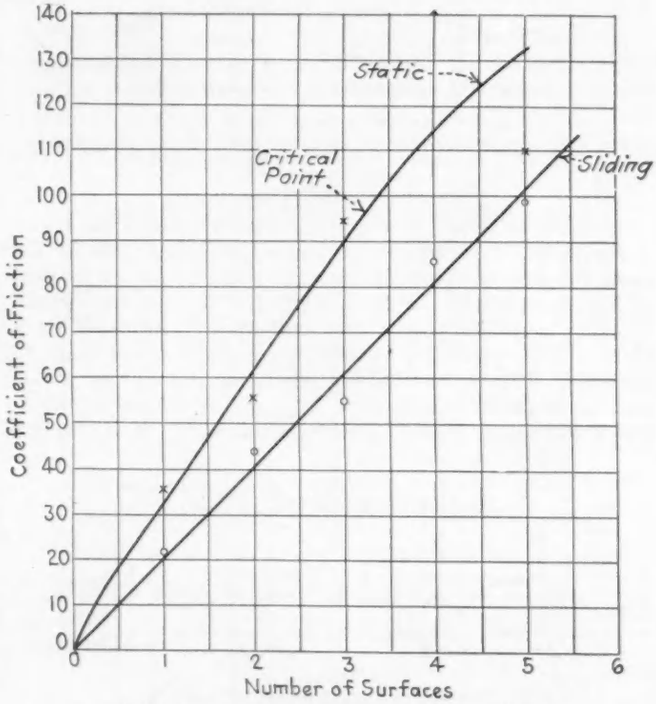


FIG. 13—RESULTS OF TESTS ON DRY SURFACES

The Relation Between the Coefficient of Friction and the Number of Surfaces Is Shown for Dry Steel-Plates Having a Surface Area of 25 Sq. In.

Fig. 13 shows the results of tests on dry surfaces. The curves illustrate the relation between static and sliding friction and the number of surfaces in contact. It is obvious that the percentage of increase of static friction over sliding friction decreases as the number of surfaces increases, and it is logical to conclude that the line showing static conditions will meet that showing sliding conditions somewhere beyond the critical point. The coefficient of sliding friction between two dry steel-plates was found to be 22 per cent and that of static friction to be 35 per cent. The increase in resistance varies in direct proportion to the number of surfaces.

The results of studies of lubricated surfaces are outlined in Fig. 14. The loads are applied to a plate having an area of 25 sq. in.; hence, the unit pressure will be found by dividing the figure representing the load by 25. The lowest coefficient of friction was obtained by using a mixture of 50 per cent of powdered graphite and 50 per cent of cylinder oil by volume, and the dash-and-dot line illustrates this condition. The close proximity of the lines indicating static and sliding friction, and also the smoothness of the curves, should be noted

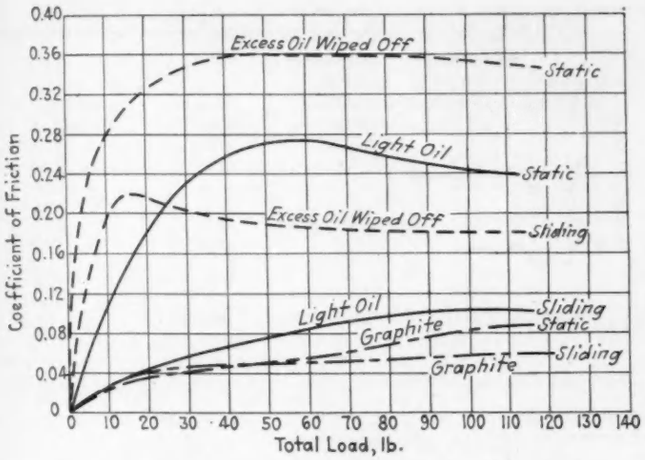


FIG. 14—RESULTS OF STUDY OF LUBRICATED SURFACES
The Loads Were Applied to a Plate Having an Area of 25 Sq. In. in Determining the Coefficient of Friction for Plain Steel-Surfaces Lubricated with Cylinder Oil and a 50 Per Cent by Volume Mixture of Graphite. The Full-Line Curve Indicates the Results from Using Light Oil; the Dash Line, Those When Excess Oil Was Wiped Off; and the Dot-and-Dash Line Those When Graphite Was Used

particularly. The full line shows the result of using cylinder oil in liberal amount; the dash line, the result of using the same type of oil with the excess oil wiped off. The curves showing the coefficients of static and of sliding friction will coincide eventually when the pressure becomes sufficient. In the case of lubrication with graphite, this meeting of the curves takes place at a pressure of 1¾ lb. per sq. in., after which point there is a peculiar divergence of the curves which is due to the pressing down of the thick film; but beyond that pressure the lines will coincide again.

The important conclusion to be derived from these tests is the fact that graphite maintains an almost constant coefficient of friction. In conventional spring-making, graphite is applied sparingly.

DYNAMIC TESTS OF LEAF SPRINGS

For the purpose of investigating the vibration qualities of springs and with particular emphasis on the correlation of static and dynamic friction with vibration qualities, we designed and built recently a special machine which is shown in Fig. 15. Adjustable features in the design of this machine permit vibration tests to be made on all ordinary passenger-car springs. The force which sets up vibration is delivered by a variable weight which is always made to represent the normal carrying-load. This weight is lifted by a constant-acceleration cam to a predetermined point; then it is released sud-

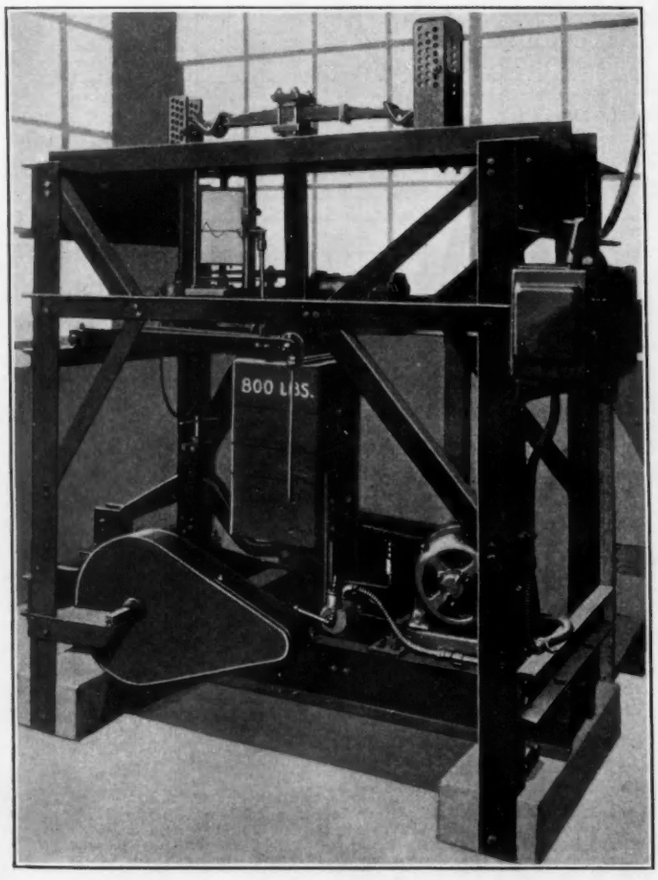


FIG. 15—APPARATUS FOR INVESTIGATING THE VIBRATION QUALITIES OF SPRINGS
Adjustable Features in the Design of This Machine Permit Vibration Tests To Be Made on All Ordinary Passenger-Car Springs

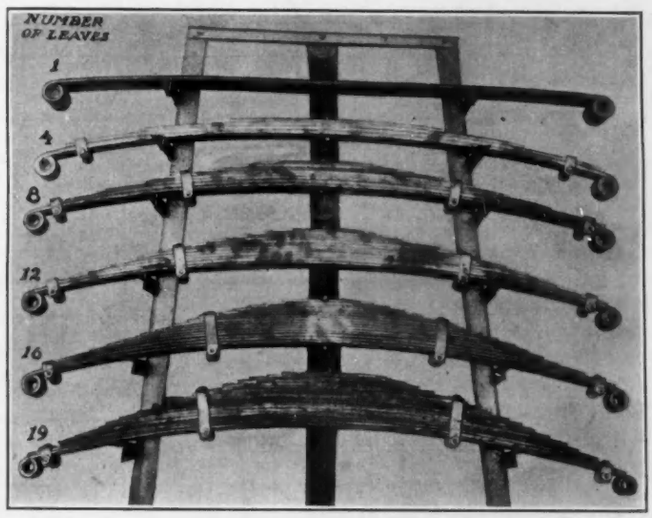


FIG. 16—INVESTIGATION OF THE EFFECT OF MULTIPLE LEAVES ON THE VIBRATION OF SPRINGS
The Springs Were Prepared According to Conventional Practice and Were Tested "Dry"; All Have a Given Flexibility Represented by a Load of Nearly 300 Lb. To Produce a Deflection of 1 In. and Are Composed of 1, 4, 8, 12, 16, and 19 Leaves Respectively as Shown

denly and its full force deflects the spring and produces a vibration. A graph of the oscillation of the spring is recorded in pencil on a drum which is driven by a constant-speed motor and, for extreme accuracy, a tuning-fork record can be made on the chart. The machine is fitted with a permanent motor-drive, by means of which life tests on springs can be made.

The tests were made with six dry springs which were prepared according to conventional practice; all have a given flexibility represented by a deflection of 1 in. resulting from the application of nearly 300 lb. of load and are composed of 1, 4, 8, 12, 16, and 19 leaves respectively. In all except the first spring, the nip was constant and equal to 200 lb. The springs are illustrated in Fig. 16 and were made for investigating the effect of multiple leaves on the vibration of springs. The frictional surfaces were cleaned by sand-blasting. A test was made on each spring in the vibratory machine, the application of force being made by an 800-lb. weight. The tests consisted of making a vibration record of each spring, following four or five initial oscillations that were intended to adjust the leaf surfaces. Following the mak-

ing of the oscillation curves, each spring was calibrated in a static-load machine up to the maximum dynamic deflection recorded and, from these results, the absorption charts shown in Fig. 17 were made. The areas in the absorption charts represent the total energy in inch-pounds from zero to the maximum deflection; but, while this has a very important relationship to the vibration of springs, it cannot be used alone to study the comparative vibration qualities of springs, as will be clearly shown later.

In Fig. 18, an actual reproduction is given of the oscillatory waves for the springs tested. The great effect of friction is apparent. Table 1 gives a collection of the important data measured and calculated from the vibration curves of the springs tested. Column 2 of Table 1 lists the number of periods required to damp each

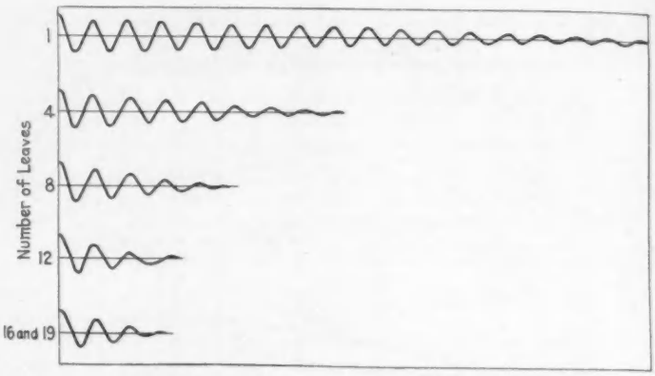


FIG. 18—CURVES REPRODUCED FROM VIBRATORY-MACHINE RECORDS

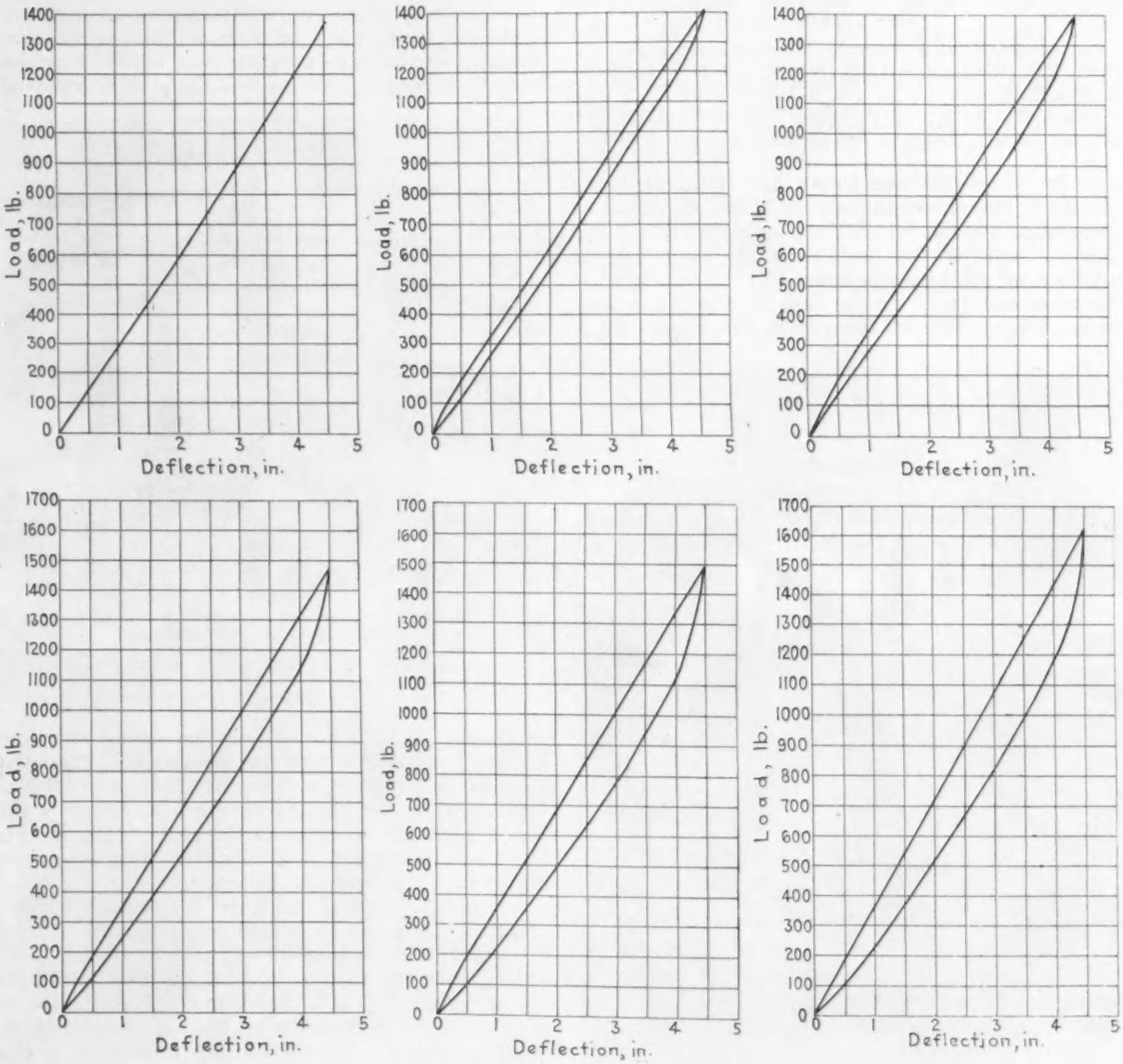


FIG. 17—ABSORPTION CHARTS FROM CALIBRATION TESTS

The Curve in the Upper Left View Is for a Single-Leaf Spring 3 In. Wide and 37½ In. Long Having No Nip and a Flexibility Represented by a Load of 298¾ Lb. The Four-Leaf Spring, the Curve for Which Is Shown in the Upper Central View, Was 2 In. Wide and 39 In. Long; It Had a Nip of 200 Lb. and a Flexibility Represented by a Load of 302 Lb. In the Upper Right View the Curve for an Eight-Leaf Spring 2 In. Wide and 39 In. Long Is Shown; It Had a Nip of 200 Lb. and a Flexibility Represented by a Load of 292 Lb. The Curve in the Lower Left View Is for a 12-Leaf Spring 2 In Wide and 39 In. Long, Having a Nip of 200 Lb. and a Flexibility Represented by a Load of 303 Lb. In the Lower Central View Is the Curve for a 16-Leaf Spring 2 In. Wide and 39 In. Long, Having a Nip of 200 Lb. and a Flexibility Represented by a Load of 292 Lb. The View at the Lower Right Is the Curve for a 19-Leaf Spring 2 In. Wide and 39 In. Long Having a Nip of 200 Lb. and a Flexibility Represented by a Load of 330 Lb.

TABLE 1—RESULTS OF VIBRATION TESTS OF SPRINGS HAVING CONSTANT NIP AND FLEXIBILITY

No. of Spring Leaves	No. of Periods	Vibrations per Minute: Actual Frequency	Vibrations per Minute: Theoretical Frequency	Static Absorption, In-Lb.
1	21½	116.0	115	0
4	6½	120.4	116	333
8	3½	118.2	114	424
12	2½	120.7	116	612
16	2½	123.0	114	784
19	2½	132.0	121	872

spring. Column 3 gives the frequency of vibration, which was calculated from the vibration records. Values of the theoretical frequency given in Column 4 are calculated from the formula $F = (60 / 2\pi) \sqrt{(12\ g / D)}$, where D is the initial deflection under load in inches and F is the frequency in vibrations per minute.

Relation of Number of Spring Leaves to Damping

A very important conclusion derived from the foregoing tests expresses a definite mathematical relationship between the number of leaves and the number of periods required to damp a spring. The curve in Fig. 19 is plotted on a logarithmic chart which expresses this relationship mathematically by the curve form $Y = 2.16 / X^{0.867}$. Thus it is evident that the number of periods of vibration of a spring is a logarithmic function of the number of plates, other things being constant. At the point j, the slope of the curve changes abruptly and, from 12 leaves upward, the number of periods remains constant, which agrees with the results obtained by N. E. Hendrickson, as stated in his paper on Studies of the Oscillation of Automobile Leaf-Springs[5].

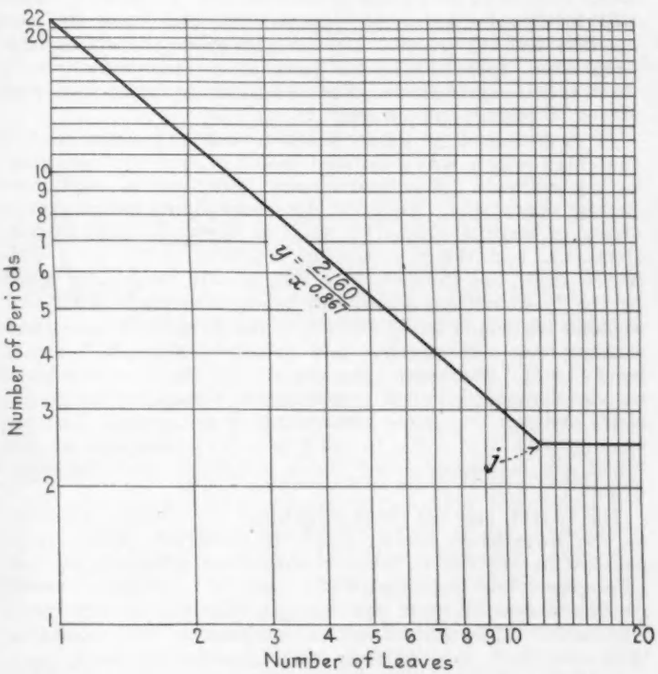


FIG. 19—CURVES SHOWING A DEFINITE MATHEMATICAL RELATIONSHIP BETWEEN NUMBER OF LEAVES AND NUMBER OF PERIODS REQUIRED TO DAMP A SPRING

The Curve Is Plotted on a Logarithmic Chart and Expresses the Relationship by the Curve Form $Y = 2.16/X^{0.867}$. All Factors other than the Relation of Number of Leaves to Damping Are Constant

Column 3 of Table 1 gives the actual frequencies, which differ considerably from those determined theoretically. The actual frequency in every case is faster, due principally to the interleaf friction but also due to a slight amount of shackle and testing-machine friction. This particular feature was found valuable in the discovery of a means to determine actual frequencies of vibration of springs by the addition of a friction-constant to the fundamental formula; that is, the deflection scaled from the compression line of the absorption chart at the 800-lb.-load mark, when substituted for D in the formula, will give very closely the actual frequency in vibrations per minute, thus eliminating the necessity for making a vibration test to determine the frequency. The inch-pounds of energy absorbed represents the absorbing ability of each spring and it is found that, other things being equal, the absorption varies practically with the number of leaves, but the only apparent effect of absorption beyond a limit of 12 leaves exists as a slight increase in frequency and not as a decrease of the number of periods.

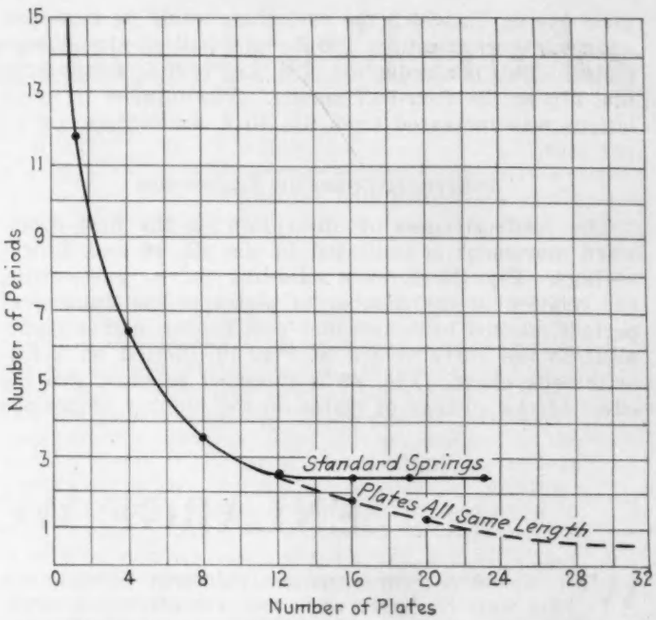


FIG. 20—RELATION OF NUMBER OF PLATES TO NUMBER OF PERIODS

The Solid-Line Curve Represents the Relation of the Number of Plates to the Number of Periods, Plotted to Rectangular Coordinates, and Is Equivalent to the Curve in Fig. 19 Plotted on a Logarithmetic Chart. The Effect of the Number of Plates on the Number of Periods When the Leaves of the Springs Are All of the Same Length Is Represented by the Dash Line

The damping of a vibrating spring is affected relatively little by nip. For example, in the case of the four-

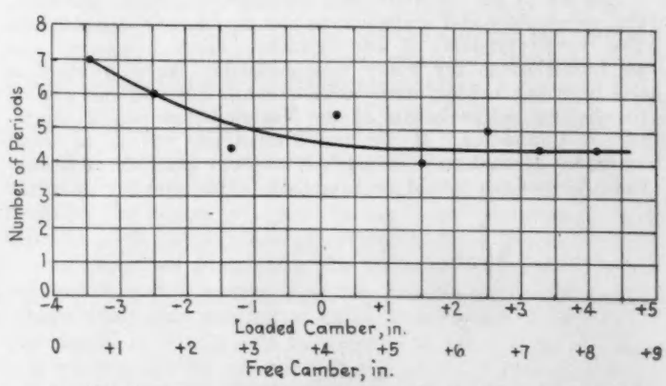


FIG. 21—RELATION BETWEEN CAMBER AND NUMBER OF PERIODS

The Abscissas Are in Two Units, Showing the Value for Both Loaded and Free Camber. The Spring Was Vibrating under an 800-Lb. Load and Had an Average Flexibility Represented by a 200-Lb. Load

[5] See THE JOURNAL, November, 1926, p. 501.

plate spring, in which the variations would be most pronounced, there is only a 100-lb. total-pull or nip between plates. This is a reduction of 50 per cent from the original nip in the four-leaf spring. The number of oscillations was increased from 6½ to 7, an increase of 7.7 per cent.

Ineffectiveness of Absorption

The ineffectiveness of absorption on the first downward movement is indicated in the 12, 16 and 19-leaf springs. Fig. 20 shows a solid-line curve, representing the relation of the number of plates to the number of periods, plotted to rectangular coordinates, and is equivalent to the curve shown in Fig. 19, plotted on a logarithmetic chart. Fig. 20 is intended to show also the effect of the number of plates on the number of periods when the leaves of the springs are all of the same length, and this effect is represented by the dash line. Suitable tests on springs having different numbers of leaves, varying from 4 to 17 and all of the same length, were made in accordance with the foregoing procedure to determine this relationship; and it is shown that in the nine conventionally designed springs, after 12 plates are reached, the interleaf friction ceases to be a factor in the damping because the percentage of friction added becomes too small.

The influence of camber on damping is illustrated in Fig. 21. The abscissas are in two units, showing values for both loaded and free camber. The damping is nearly constant when loaded camber is zero or above; but damping becomes less as loaded camber changes into reverse.

ENLARGE WORLD DEMAND

WHY should not our organized industries combine efforts with European and other manufacturing countries to increase legitimately world consumption? This is entirely different from combination to divide up the trade of the world. Its purpose would be to enlarge world demand and keep all production facilities busy.

Mankind is just awakening to many of its needs. It is willing to work harder to satisfy them. This extra labor will supply the goods to pay for more of our products. International organization of each industry can point the way to greater world production and consequent consumption. The first incentive must be the desire to consume.

The world can buy only as it produces more in each separate country. This means greater wealth and the immediate raising of living standards.

I believe that our great natural resources are a smaller factor in our present-day prosperity than is customarily thought. American manufacturing and business methods have created a wonderful consumptive demand. Money has been circulated more rapidly. The very size of our production and consequent competition is stimulating new ways of manufacturing that are better and cheaper. Europe has great productive capacity, but local markets are unwilling to buy in sufficient quantities and world markets are relatively undeveloped.

The conservative methods of our forefathers no longer suffice. In Europe, where older conservative manufacturing policies obtain, the difficulty of making some business pay is harder than ever. We see this same condition in the United States where certain industries have migrated to other sections because of the more virile and progressive leadership elsewhere.

Are we in the motor-vehicle industry content to let bankers, economists and statisticians tell us what is our market? The very freedom of our industry from precedent has permitted us to try many new methods. Mass production has been our hobby; mass salesmanship I would call one of the distinct achievements of our National Automobile Chamber of Commerce. If we had limited our efforts to what statistics seemed to demonstrate was our possible consumption, motor-cars would be produced in far smaller quantity and sold at much higher prices. Our watchword has been lower cost, finer goods and greater values. These three items will always increase the consumption and open up new markets for any goods. Most of our great industries have progressed upon this same basis in recent years. So it must be for world trade. But in this we must all deal with strong foreign competition.

It is a source of great pride to our industrial leaders that high wages are a natural result of our new manufacturing methods. Europeans come here now to study our factory operations. All great American plants have a steady string of visiting industrialists from Great Britain, France, Germany, and other producing countries. We have welcomed them, for prosperity in Europe will be greatly aided by the most efficient method of manufacturing. With consequent lower prices of products, the volume of European consumption will increase and greater individual contentment result. We must take the chance that our mechanical developments, inventiveness, sensitiveness to world desires, and our enormous home demand will always keep us on a proper cost-basis to compete. Vast markets of the world are unreached today through lack of easy communication.

The world has not been organized for credit extension on the installment basis. Here, if sound and experienced policies are instituted, international mass salesmanship can help greatly in widening world demand. America cannot do this alone. Neither can Europe. Let us combine with Europe for the benefit of our export trade as well as theirs. With the funds derived from this increased trade, in turn we will buy directly or indirectly from the countries which buy from us.

I believe this a constructive program. Here is a common ground upon which particularly Europe and the United States can meet, breaking down the natural suspicion of competitors, raising the code of international competitive ethics and making world mass salesmanship increase the wealth not of a few countries but of all countries.

Is not such international cooperation of industries our logical goal in foreign trade?—R. D. Chapin, president of the National Automobile Chamber of Commerce.

Vol. XXI September, 1927 No. 3

Six-Cylinder Engines for Trucks

By Ethelbert Favary[1]

Southern California Section Paper *Illustrated with* Diagram and Charts

ONLY recently have the merits of the six-cylinder engine for freight and for mass passenger-transportation been appreciated, according to the author, who summarizes the advantages as (*a*) 50 per cent more power-strokes per revolution of the crankshaft than in the four-cylinder engine; (*b*) overlapping of the power-strokes, which gives more constant driving-torque and decreases intensity of vibrations; (*c*) greater power obtainable, with corresponding decrease in weight of reciprocating parts; (*d*) quicker acceleration, due to the foregoing; and (*e*) ability to run at high speed without laboring.

Contrary to former belief, it has been shown that the uptodate six-cylinder engine has greater thermal efficiency than the four-cylinder engine, the author asserts. Despite the possible greater loss of heat through the cylinder-walls due to the larger ratio of wall area to cylinder volume, the engine is capable of transforming a larger number of heat units into useful work, because of reduced vibration and, perhaps most important, it is possible to use higher compression-pressure without detonation. Sufficient importance has not been placed on this possibility. Heat is conducted away from the top centers of small pistons to the cylinder-walls more readily than from larger pistons, hence the centers are cooler; moreover, in the smaller combustion-chambers the distance from the spark-plugs to the farthest layers of the combustible mixture may be less, and therefore the likelihood of part of the unburned charge becoming heated to the point of detonation by the burning charge is decreased. Consequently, a small-bore engine makes possible the use of higher cylinder-wall temperatures and higher compression-pressures.

Formulas and charts are presented to show that in high-speed engines the maximum strain on the crankshaft occurs at the end of the exhaust stroke and that the piston moves faster during the upper half of its stroke than during the lower half because of the angularity of the connecting-rod.

MECHANICAL improvements made in motor-trucks and motorcoaches have made it possible to increase the economic distance for the transportation of freight and passengers. An increased distance of travel ordinarily is accompanied by an increase in the time consumed for such travel, and this brought about a demand for powerplants capable of furnishing sustained speeds and freedom from vibration. Increasing the speed reduces the time of travel, while freedom from vibration reduces the strain on the operator as well as that on the entire mechanism. It is this demand for increased speed and distance work which suggested the use of the six-cylinder engine for trucks. The advantages of the six-cylinder engine for passenger-cars have long been recognized, but it is only comparatively recently that its merit for freight and for mass passenger-transportation has been appreciated. In the six-cylinder engine there are 50 per cent more power-strokes during each revolution of the crankshaft than in the four-cylinder engine, and the overlapping power-impulses give a more constant driving-torque and decrease the intensity of the vibrations arising from the explosions in the cylinders. Another advantage of the six-cylinder engine is the larger amount of power obtainable with a corresponding decrease in the weights of the individual pistons and connecting-rods; that is, in the reciprocating parts.

The pistons and connecting-rods of a six-cylinder engine are started and stopped twice in each revolution of the crankshaft. The magnitude of the force required to start and stop these parts is enormous, even when the engine is rotating at a medium high-speed, say at 1500 r.p.m. At such a speed each piston and its connecting-rod is started and stopped 3000 times per min., and it is the force required to accelerate and decelerate these masses as well as the force arising from the explosion which is setting-up the intense vibrations so often present in gasoline engines. The heavier the weights of the reciprocating parts are and the larger the diameter of the individual pistons, the greater are the stresses sustained by the engine structure and the greater are the vibrations, everything else being equal. Hence, in a six-cylinder engine, the reduced vibration is ascribable to several distinct causes: overlapping of the power-impulses, the greater number of impulses per minute, the lower intensity of each impulse, and the reduction in the weights of the reciprocating parts.

Quick Get-Away

Since the interval of time between the power-impulses in the four-cylinder engine is greater and the weights of the pistons and rods are greater than in the six-cylinder engine, a heavier flywheel is needed to prevent excessive speed-fluctuations between the power-impulses. Due to the greater number of power-impulses, the lighter weights of the individual reciprocating parts and the lighter flywheel, the six-cylinder engine has the ability to "get away" more quickly and to reach a higher speed in less time. The six-cylinder engine has the further advantage that, without "laboring," it can continue running at a higher speed and thus deliver more power.

Cylinder Diameter and Thermal Efficiency

It was thought formerly that the greater the number of cylinders was, the smaller was the thermal efficiency, because the losses of heat through the jacket-wall increased with the number of cylinders for a given power. It was reasoned that, since the ratio of wall area to the volume of the cylinders and the combustion-chamber is larger when the volume is small than when it is large, the losses of heat would be greater in an engine having a large number of cylinders for a given piston-displacement. This undoubtedly was true formerly, especially because the jacket-water temperature used to be kept lower than is now common practice. The proportion of

[1] M.S.A.E.—Consulting engineer and manager of sales promotion, Moreland Motor Truck Co., Los Angeles.

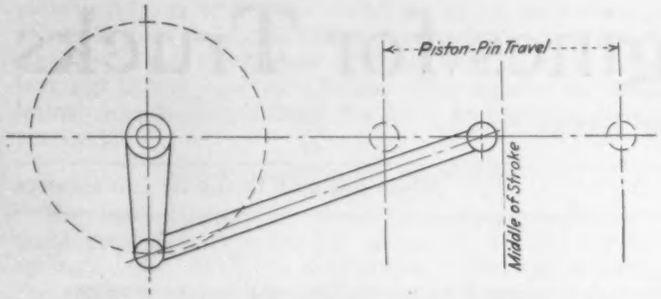


FIG. 1—VARIATION IN SPEED OF PISTON-TRAVEL

The Diagram Illustrates That the Piston Travels Faster during the Upper Half of the Stroke, Due to the Angularity of the Connecting-Rod. The Crankshaft Is Shown at One-Quarter Revolution, Starting from the Top; Yet the Piston and the Piston-Pin Have Traveled Considerably More Than One-Half of the Length of the Stroke. As the Crankshaft Rotates at Practically a Uniform Speed, the Piston Will Travel Considerably Faster during the Upper Half of the Stroke than during the Lower Half; Consequently, the Force Required To Accelerate and Decelerate the Piston Is Considerably Greater on the Upper Half of the Stroke

wall area exposed to the hot gases naturally increases with an increase in the number of cylinders.

While the losses of heat through the wall at a given wall-temperature may be greater in a six-cylinder engine than in a four-cylinder engine of a given piston-displacement, the increased efficiency due to reduced vibrations and, what is perhaps most important, the possibility of using a higher compression-pressure, have shown the six-cylinder engine to be capable of transforming proportionately a larger number of heat units into useful work than is possible with the four-cylinder engine of the same power.

It is believed that sufficient importance has not been placed on this possibility of using higher compression-pressures for engines of smaller bore without incurring detonation. If we accept the theory that detonation occurs when the increase in the heat of a portion of the unburned charge, due to the compression of the burning gases, exceeds by a certain margin the heat dissipated through the cylinder-wall and piston, an engine of smaller bore should be capable of using high compression-pressures. The center of the piston-head is at a higher temperature than the rest of the piston or the cylinder-wall, and the larger the diameter of the piston is, the greater is the distance of the center of the piston-head from the cylinder-wall. Since the piston is cooled chiefly through the cylinder-wall, it follows that the temperature of the center of the piston increases with its diameter. Therefore, a larger piston would necessitate a lower wall-temperature to prevent the center of the piston-head from reaching the temperature which would be conducive to detonation at a given compression-ratio, and, if the wall-temperature is reduced, the thermal losses through the wall are increased.

Another advantage of a smaller combustion-chamber volume is that the distance from the spark-plug points to the farthest layers of the combustible mixture can be made shorter and, the shorter this distance is, the less is the possibility of detonation because there is less likelihood of a portion of the unburned charge becoming heated by the burning charge to the point of detonation. Hence, an engine of small bore permits the use of higher wall-temperatures and higher compression-pressures.

PISTON TRAVELS UPPER HALF-STROKE FASTER

We sometimes neglect to consider the facts that, in high-speed engines, the maximum strain on the crankshaft occurs, not when the explosion takes place, but at the end of the fourth or exhaust stroke, and that the piston travels faster during the upper half of the stroke due to the angularity of the connecting-rod. The crankshaft in Fig. 1 is shown at one-quarter revolution, starting from the top, yet the piston-pin and the piston have traveled considerably more than one-half of the length of the stroke. As the crankshaft rotates at practically a uniform speed, the piston will travel considerably faster during the upper half of the stroke than during the lower half; consequently, the force required to accelerate and decelerate the piston is considerably greater on the upper half of the stroke, and this introduces high bearing-loads due to the inertia forces of the reciprocating parts. The following examples show how great these inertia forces are at the end of the upper stroke, thereby causing greater bearing-loads and in many cases more wear at the lower side of the connecting-rod bearing than on the upper side, which sustains the gas pressure. Let

a = Acceleration, in feet per second per second
g = Acceleration due to gravity, 32.2 ft. per sec. per sec.
L = Length of the connecting-rod, in inches
N = Number of revolutions per minute
R = Radius of the crank circle, in feet
r = Radius of the crank circle, in inches
v = Linear velocity of the center of the crankpin, in feet per second
W = Weight of the reciprocating parts; that is, the weight of the piston complete and the upper half of the connecting-rod, in pounds
w = Weight of the lower half of the connecting-rod with its bearing, in pounds

The inertia force F_i, in pounds, of a moving mass is

$$F_i = W a/g \quad (1)$$
$$= 0.00034\, WRN^2 (\cos A + [r/L] \cos 2A) \quad (2)$$

where A is a given angle of the crank arm.

For the derivation of equation (2), reference is made to Chapter XII of my book[2].

As an example, consider the original Class-B engine, which had a connecting-rod length of 13¼ in., a crank radius of 3 in., a piston weight of 6¼ lb., and a weight for the upper end of the rod and wristpin of 3¾ lb. Hence, the total reciprocating weight was 10 lb. At 1500 r.p.m., which was the speed of maximum power of this engine, the inertia force of the reciprocating parts at the end of the fourth stroke is:

$$F_i = 0.00034 \times 10 \times 0.25 \times 1500^2 \times 1.222 \quad (3)$$
$$= 2340 \text{ lb.}$$

To find the crankpin-bearing load, we must add the centrifugal force to the inertia force, since this centrifugal force acts always outwardly from the center; hence, at the end of the lower or upper stroke, it must be added to the inertia force to obtain the bearing load.

The lower end of the connecting-rod with its bearing, which is usually considered in figuring the centrifugal force, weighed 5½ lb. To find the centrifugal force F_c, we have the formula:

$$F_c = wv^2/gR \quad (4)$$
$$= 0.00034\, wRN^2 \quad (5)$$

For the derivation of equation (5), reference is made to Chapter XII of my book[2].

At 1500 r.p.m. of the crankshaft, the centrifugal force would be

$$F_c = 0.00034 \times 5.5 \times 0.25 \times 1500^2 = 1052 \text{ lb.}$$

Hence, the crankpin-bearing load at the upper end of the fourth stroke equals 2340 lb. + 1052 lb. = 3392 lb. At the end of the first and third strokes the inertia force F_i = 1485 lb. The bearing load would, therefore, be

[2] See Motor Vehicle Engineering, by Ethelbert Favary.

1485 + 1052 = 2537 lb. At the end of the third stroke we must add the gas pressure remaining in the cylinder, which probably would increase the pressure on the piston by about 300 lb. Hence, we have a bearing load of 2537 + 300 = 2837 lb. at the lower end of the stroke, compared with 3392 lb. at the upper end of the stroke. This accounts for the increased bearing wear on the lower half of the connecting-rod bearing in high-speed engines. On the second stroke the bearing loads will be lower because of the counter-pressure due to the compression of the charge.

If we take the gas pressures at the beginning of the power-stroke at 280 lb. per sq. in., the total pressure on the piston-head amounts to 4965 lb. As the reciprocating weight comes to a standstill at the upper end of the stroke, the inertia forces of the reciprocating parts now oppose the gas pressure and we must deduct this inertia from the total pressure; hence, the downward pressure on the piston is 4965 lb. minus the inertia force of 2340 lb. and minus the centrifugal force, which always acts outward from the center of the shaft. Therefore we have 4965 — 2340 — 1052 = 1573 lb., showing that the crankpin pressure is considerably lower on the beginning of the power-stroke than at the end of the fourth stroke.

Aluminum Piston and Rod Bearing-Load

Let us now analyze the crankpin pressure with an aluminum piston and an aluminum connecting-rod, assuming their weight as one-half that given previously for the cast-iron piston and the steel connecting-rod. In this case the centrifugal force caused by the lower end of the rod is $0.00034\ wRN^2 = 0.00034 \times 2.75 \times 0.25 \times 1500^2 = 526$ lb.

The inertia force at the end of the fourth stroke is $0.00034\ wRN^2\ (\cos A + [r/L] \cos 2A) = 0.00034 \times 5 \times 0.25 \times 1500^2 \times 1.222 = 1170$ lb., and adding 526 lb. = 1696 lb. as compared with the 3392 lb. obtained in the previous example. At the beginning of the third stroke the pressure would be 4965 — 1170 — 526 = 3269 lb., which is considerably higher than the pressure found in the previous example at the beginning of the power-stroke.

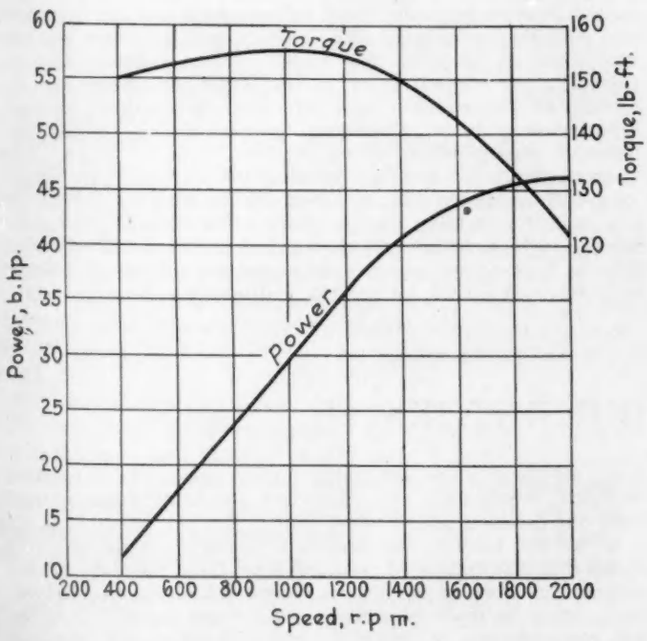


Fig. 2—Characteristic Curves for a Four-Cylinder Engine
The Engine Has a 4-In. Bore, a 5-In Stroke and a Piston-Displacement of 251.3 Cu. In.

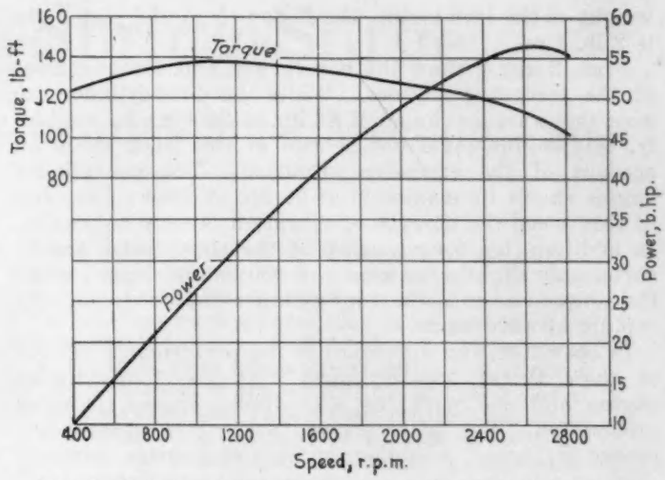


Fig. 3—Characteristic Curves for a Six-Cylinder Engine
The Engine Has a 3¼-In. Bore, a 4⅝-In Stroke, and a Piston-Displacement of 230.2 Cu. In.

Bearing Pressures on the Wristpin

The weight of the cast-iron piston in the Class-B engine was 6¼ lb.; therefore, the inertia force due to this weight alone at the beginning of the third stroke is 1460 lb. and the pressure on the piston-pin equals the total gas-pressure, 4965 lb., minus the inertia force of 1460 lb. = 3505 lb. With an aluminum piston of one-half the weight the inertia force would be 730 lb.; therefore, the wristpin pressure would be 4965 — 730 = 4235 lb., or about 20 per cent more than in the first case. Thus we can see that the maximum pressure per square inch of projected area on the wristpin is higher with aluminum pistons than with cast-iron pistons.

Stresses in Connecting-Rods

The stresses in aluminum connecting-rods are considerably higher than those in steel connecting-rods. At the beginning of the power-stroke the compression-stress in the duralumin connecting-rod, with aluminum pistons, is the gas pressure minus the inertia force, or 4965 — 1170 = 3795 lb., as compared with 2625 lb.; that is, the gas pressure of 4965 lb. minus the inertia force F_i of 2340 lb. as found before for cast iron, or almost 50 per cent higher than it was before. Since aluminum rods cannot withstand a higher compression than steel, allowance must be made for this fact when designing engines with duralumin connecting-rods. No doubt the failure of many duralumin connecting-rods should be ascribed to the higher stresses in the rods, due to the lighter weight of rods and pistons, rather than to the lesser strength of duralumin.

Comparison of Four and Six-Cylinder Engines

It will no doubt be of interest to compare the difference in the actual results obtained with four-cylinder and with six-cylinder engines having approximately the same piston-displacement. In a certain 1-to-2-ton truck, until comparatively recently, a well-known four-cylinder engine was used that had a 4-in. bore and a 5-in. stroke and a piston-displacement of 251.3 cu. in. The weight of the steel connecting-rod was 3 lb. 6 oz. and that of the piston with piston-pin and piston-rings, 4 lb. 0 oz. A six-cylinder engine of another equally well-known make was substituted, having a 3¼-in. bore, a 4⅝-in. stroke and a piston-displacement of 230.2 cu. in. The weight of the steel connecting-rod is 2 lb. 6 oz. and the

weight of the iron piston, the piston-rings and piston-pin is 2 lb. 1 oz.

Figs. 2 and 3 show the horsepower and torque curves of the foregoing engines. While the four-cylinder engine shows its maximum of 46 hp. at 2000 r.p.m. normally, this engine could not be run at this high speed on account of the excessive vibration. The six-cylinder engine shows its maximum of 56 hp. at 2600 r.p.m., and at this speed the absence of vibration is very noticeable. In addition, the torque curve of the six-cylinder engine varies only slightly for speeds of 400 to 2600 r.p.m., while the torque curve of the four-cylinder engine drops very rapidly at 1200 r.p.m.

In operation, the difference in the performance of two of these trucks, one equipped with the four-cylinder engine and one with the six-cylinder engine, is most pronounced. The latter showed not only a greatly improved get-away, a higher speed and a more constant torque at all speeds, but the economy is one of the outstanding factors which truck operators in the future will no doubt consider seriously. With the four-cylinder engine in this truck, 10 miles per gal. was considered very good fuel-consumption with the normal load of 2 tons, while with the six-cylinder engine from 12 to 13 miles per gal. is the usual performance. In other words, the increased mileage per gallon of 25 per cent, besides the almost total absence of vibration, the increased speed, quicker get-away and improved all-round performance of the six-cylinder engine, is the best possible proof that we may look forward to a still more rapid adoption of the six-cylinder engine for commercial vehicles in the future. It is confidently expected that engine builders will increase the compression-pressure in the engines of small bore, and therefore that the efficiency and the gasoline economy of the six-cylinder engine will be even greater than those just noted.

BETTER USE OF COAL

IN 1840 practically no coal was mined in the United States. In 1860 our production was only a few million tons. In 1918 production reached a peak of about 740,000,000 tons. It is now, under the competition of fuel oil and because of more efficient use, down to about 600,000,000 tons.

In 1860 the annual per capita consumption of petroleum in the Country was 0.016 bbl. or a production of 503,141 bbl. We are now producing nearly 2,500,000 bbl. per week and importing oil at that.

At the recent notable International Conference on Bituminous Coal, President Baker, of Carnegie Institute of Technology, said:

> In less than a generation the present method of shipping coal to be burned in its raw state under boilers hundreds of miles from the mines will appear to have been primitive and rudely unscientific.

Some 200 processes for so-called low-temperature carbonization of coal have been listed, but it is doubtful if 10 per cent of that number have been operated on anything approaching the commercial scale. Their distinguishing characteristic is that the coal is carbonized at temperatures rarely exceeding and often below 1100 deg. fahr. As a result, there are obtained a moderate volume of gas of high heating power and valuable, in place of gas oil, for the enrichment of blue water gas, an excellent smokeless fuel in the form of semi-coke, and from 20 to 40 gal. of a thin tar per ton of coal. This tar is markedly different from ordinary coal tar and has, instead, much of the character of petroleum. It may be cracked to yield 22 per cent of motor fuel of high antiknock quality. Much serious work is being done on low-temperature carbonization in England and Germany, and it is claimed that one or two processes at least, the Coalite process in England and notably the K. S. G. process in Germany, are on a commercial basis. The latter is operating at Essen on a considerable scale, and a plant to handle 500 tons of raw coal per day is now under construction in South Wales. It is doubtful if there is yet in this Country a process that can be said to have established definitely a successful commercial status. It seems, nevertheless, altogether probable that within a short time certain of the processes now in the development stage will take an assured and important place in fuel technology.

In 1925 there were sold in the United States 422,000,000,000 cu. ft. of manufactured gas, whereas only 112,000,000,000,000, if one can apply the word "only" to figures of such astronomical dimensions, were sold in 1905, an increase of 376 per cent in 20 years. With the industry facing a five-fold further increase in the next decade or two, factors similar to those which have determined the integration of the production and distribution of electricity may be expected to bring about a like development in the manufacture and distribution of gas. We shall do well to watch the development of projects now under serious consideration in Germany for concentrating in the Ruhr the entire gas industry of the country and effecting distribution through high-pressure lines. Coke-oven gas is already being distributed over a radius of 62½ miles from the Ruhr. The Germans believe that the problem of leakage over much longer lines under higher pressures is entirely solved by processes for welding the gas lines. The distant gas transmission will, it is thought, be subject to the same economic laws as high-tension electric transmission.—From an address by Arthur D. Little, before the Engineering Foundation.

SCIENCE AND BOLSHEVIKS

IT is a wise nation that knows its own bolsheviks. The most dangerous bolsheviks do not wear red neckties nor write radical pleas. Someone should sound the tocsin for a new kind of bolshevik hunt; a hunt for unsuspected bolsheviks. The real bolsheviks of business fall readily into two groups: First, those who are apostles, not of red theory, but of red tape; and second, those whose blundering administration puts the balance sheet of a business in the red.

All the sciences have lying, relatively unused, in their laboratories socially usable ideas that would, if really used, lift the whole tone and temper of American life. Unfortunately, many of these ideas are today buried under the jargon of technical scholarship and effectively insulated from contact with our common life.

If we are to save the results of scientific research from slander at the hands of demagogs or from sterility as the private luxuries of highbrows, some soundly conceived attempt must be made to winnow out the net social and spiritual contributions of scientific research from the chaff of attendant detail, and then these contributions must be translated into the common tongue of the people.—Glenn Frank in *Class*.

Notes on Valve-Spring Surge

Discussion of Donkin and Clark Semi-Annual Meeting Paper

A STUDY of the influence of vibration on valve-springs reveals two possible ways in which a valve-spring can vibrate: First, when the frequency of the forced vibration is low, the force tending to vibrate the spring is small, due to the comparatively small centrifugal effect of the valve-operating cam, and the time between applications of the force is long enough to permit the vibrations set up in the spring to die out between successive applications of the force, hence the spring vibrates as a part of the entire vibrating system. Second, if the forced vibration is of a rather high frequency and is of such a value that it is an arithmetical factor of the natural frequency of the spring, a condition of resonance may be set up whereby the spring vibrates in itself at its own frequency.

An analysis of surge effected with the aid of a super-speed motion-picture film and the vibroscope, which were used in conjunction with a valve-gear testing-machine, reveals that, when the spring is vibrating in its own period, at a given instant certain adjacent coils may be spread apart beyond their normal position for an equivalent static compression and that, an instant later, the condition of these coils may be exactly reversed so far as deflection is concerned.

The abnormal compression of the coils at one instant and abnormal opening of the same coils at the very next instant cause the existence of a stress and a stress range that are much greater than those calculated by conventional formulas. Furthermore, the stress range is passed through in a time equivalent to that required for the completion of one wave of the natural period of the spring. This time factor, combined with the stress conditions existing, tends to accelerate greatly the fatigue of the valve-spring. Accordingly, the condition described is a very prolific cause of valve-spring failure.

The discussion deals with the relation of other vibrating elements in the engine and other parts of the chassis to valve-spring vibration; study of rapidly moving parts with the aid of the oscilloscope; maximum input-impulse frequency that can be used without creating undue noise in the valve-spring; varying effects of torsional vibration of the camshaft at different locations on the shaft; how the spring-vibration values check with calculations by Ricardo's formula for frequency expressed in cycles; and increasing the static stress in the valve-spring to prevent surging that causes repeated breaking of springs at a certain coil.

CHAIRMAN H. L. HORNING[2]:—The more we get into higher engine-speeds the more necessary it is to know more intimately what is going on in the engine. Two or three years ago our company had a serious problem in valve procedure and bought an oscilloscope, which is a very adaptable form of stroboscope, to assist in solving it. I think the instrument cost between $800 and $1,000, and every time I looked at it I wondered if we had not been rather rash. About eight times a year, however, we have put the instrument to work, and it pays for itself. I am pleased at times also to feel that we have been of service to our friends. We either have it in use ourselves or it is in the laboratory of some company that is friendly to us.

This instrument reveals what is happening at speeds that the human eye cannot follow. Very often our imagination leads us astray as to what is occurring. In one case a certain oil-thrower was put on a shaft and a hole was made in a bearing to catch the oil from this thrower. By putting the oscilloscope in action we found that the oil was not thrown anywhere near the opening in the bearing. Not one engineer in 10,000 would ever guess the action of that oil-thrower as shown by the oscilloscope.

The oscilloscope is of particular interest in connection with the study of valve surge. In these days of high engine-speeds and valves sometimes 2½ in. in clear diameter, we are confronted with some serious problems with valve-springs. Spring surge belongs to a class of problems which I recommended to the Society as a subject for an entire meeting session; that is, synchronous-vibration effects in the mechanism of an automobile. Spring surge has an important influence on the operation of an engine. We do not all realize that some of the peculiar things that happen to valves are due entirely to spring surge.

Relation of Impulse Frequency to Noise

R. V. HUTCHINSON[3]:—Have the authors given any study to the question of how close one may approach synchronism for a given condition of border-line unpleasantness in noise; that is, the maximum permissible input-impulse frequency in terms of the natural frequency? To illustrate, when using a spring having a natural frequency of, say, 150 cycles per sec., should the input-impulse frequency be confined to, say, 15 cycles per sec., or is it permissible from the noise standpoint to go on up to say 25 or 30 cycles per sec.?

W. T. DONKIN:—I cannot say that we have studied that in particular. As a rule the greater noise will be at higher speeds; that is, as the amplitude of the vibration is increased and the coils clash with one another. It is impossible to foretell at what speed the greatest noise will be created because other factors enter into the nature of the surge. We get maximum noise at certain speeds and at the next higher speed the noise will be less. This is due to some extent perhaps to a resonant condition of another valve-gear part affecting the surge of the spring, but we have not proved this yet; it is only an inference.

MR. HUTCHINSON:—If we plot a lift-time diagram of the forced motion of the end of the valve and tappet, we find that for a considerable portion of the cycle the lifter and spring are intended to be stationary. Analyzing such a curve harmonically, we find it is composed of a constant term plus a series of harmonics of increasing frequencies and varying amplitudes. In one example I

[1] The paper, which was illustrated, was published in the June, 1927, issue of THE JOURNAL. Both authors are engineers connected with the Cleveland Wire Spring Co., Cleveland.

[2] M.S.A.E.—President and general manager, Waukesha Motor Co., Waukesha, Wis.

[3] M.S.A.E.—Designing engineer, Olds Motor Works, Lansing, Mich.

checked in this way I found the third harmonic to be of greatest amplitude, and certain springs tested with such a cam showed noisy action when the springs were excited at one-sixth their natural frequency. Perhaps some factor other than the springs enters into the matter. Have we yet studied much of the nature of the exciting motions? Has any work been done using, instead of a cam, a plain eccentric which, with a flat lifter, should give as closely as possible a simple harmonic motion of the spring end? If that has been done what, if any, is the difference in action of a given spring when it is actuated by an eccentric instead of being cam actuated?

MR. DONKIN:—The research on valve-spring surge that we have started has led us into this field. We now have valve-springs on test and are using an eccentric rather than the cam to get their vibrational characteristics under these conditions. However, as that test was started about a month ago, we have no data to give pertaining to what we shall find as the result of using an eccentric rather than the cam.

EFFECTS OF TORSIONAL VIBRATION OF SHAFTS

CHAIRMAN HORNING:—I think it can easily be proved that the camshaft torsional-vibration at different points in the length of the shaft will have a profound effect upon the noise. If the camshaft is driven by a gear or a chain in front and the shaft is small in diameter, you will have a torsional vibration. Moving forward toward the driving gear, the torsional twist of the shaft is less and less until, at the front cam, the shaft is practically stiff. Undoubtedly some camshafts on the market do impose their own nature upon the sound that is developed by the spring.

The problem is very complicated. It must be realized that one set of periods is superimposed on another. The whole problem is not on the springs alone, because the whole mechanism is an elastic complex. The crankshaft has something to do with it. Not long ago we had an engine that was so bad in connection with electric generators that it was almost impossible to run the car because of the noise. It was surprising to find that the whole cause of this trouble was a hollow drive-shaft behind the flywheel. The size of this shaft was governed by consideration of standard transmission gears and therefore the shaft was so small that it had a vibration period well within the speeds of the engine. The result was that its vibration traveled through the crankshaft and the gears and finally erupted at the point where the lighting generator was driven and made an intolerable noise. We spent about $700 to find that out, but that was worthwhile.

[4] M.S.A.E.—Engineering department, Pierce-Arrow Motor Car Co., Buffalo.

VALUES CHECK WITH RICARDO FORMULA

MR. HUTCHINSON:—How do your values check when put into Ricardo's formula for frequency expressed in cycles per second or per minute?

MR. DONKIN:—In the original spring we use Ricardo's formula, which gives us the number of free vibrations of the spring, and this number of 10,750 we check almost exactly. There will be some variations, but the formula can be used to advantage for comparison. Certain periods will be perhaps 50 vibrations per min. or more away from the calculated figure. Ricardo gives the figure 513. We have checked back on Ricardo and find that this should be 531. We communicated with Ricardo and found that a misprint occurred in the book. If you use this formula, use 531 instead of 513.

CHAIRMAN HORNING:—As engine-speeds are increased, each speed brings on a new dynamic phenomenon. My attention has been called to the fact that beyond 2200 to 2400 r.p.m. the function of piston-rings, another form of spring, becomes all upset, and in most engines running at more than this speed it is questionable whether really good oil-sealing is maintained. An investigation is now being made which should tend to make piston-rings as effective at 3000 r.p.m. as they are at 800 to 1200 r.p.m.

What is true of the piston-ring is also true of the crankshaft. We know that periodicities are ruining many engines today. Not long ago I studied a case in which the apparent harmony between the driveshaft in the rear of the car and the crankshaft brought on an accumulated effect at 51 m.p.h. which resulted in throwing a driveshaft out of the chassis on the road. At the less destructive vibration-periods it was only a question of time when the mechanism failed. This is a problem every man building a high-speed car must solve. Some failures are almost impossible to explain unless one is well grounded in this question of synchronous vibration.

P. B. JACKSON[4]:—Is a characteristic break that occurs in the second, third or fourth coil of a valve-spring that is well within a reasonable stress caused by this surging action?

MR. DONKIN:—When breakage occurs in the same vicinity each time in a certain coil, whether the first or third active coil, I think the breakage usually is due to the over-stressed condition at this point, and the over-stressed condition undoubtedly is caused by surge.

MR. JACKSON:—We eliminated a condition of that kind by putting a ⅛-in. washer under the spring, which increased the maximum stress in the spring.

MR. DONKIN:—As a rule one of the things we do first is to increase the static stress in a spring. However, increasing the static stress does not always increase the real stress, and it is the real stress that counts, not the static stress that is calculated in the formula.

REDUCING COSTS OF FARMING

THE use of agricultural machinery has increased very swiftly in the last decade, and it appears that this year's crops will be produced at the lowest average cost in many years. The influence of these improvements in technique is apparent also in the marketing of the winter wheat crop earlier than ever before. The reduction in costs due to modern methods of cultivation and harvesting may go far toward explaining the persistence of large crop acreages in the face of the price depression of recent years. Further extension of these improvements, together with increased cooperation and better marketing methods, will contribute to a very great extent to the ultimate solution of what speakers and writers refer to as the "agricultural problem." —*Guaranty Survey.*

Vol. XXI September, 1927 No. 3

Modern Naval Aircraft

By Lieut-Com. Lawrence B. Richardson, U. S. N.[1]

Southern California Section Paper *Illustrated with* Photographs

MORE and more is being demanded of Navy airplanes beyond the requirements of commercial planes. Catapulting and deck landings are required of some planes and corrosion must be guarded against. Bombers and fighting planes each have their special requirements, and planes must be able to land safely on either land or water.

The most important developments in aerodynamics now going on are to restrict the travel of the center of pressure of the wings as the angle of attack changes; but widespread adoption of slotted wings and other results of experimental development may be expected.

Metal is being used more than formerly in structural work but there are as yet no all-metal service-types in the Navy. Chrome-molybdenum steel is replacing mild carbon-steel in the tubular frames of fuselages, and there is a tendency to seek substitutes for welded joints. Duralumin is slowly replacing steel where welding is not required, but its adoption is retarded because of corrosion. Spruce, mahogany and plywood are used for wing structures and fabric is still the standard covering-material.

Heat-treated aluminum-alloy castings and forgings are beginning to be used to a large extent. Stainless steel is expensive and not thoroughly reliable in every respect, but it may be used more as these objections are eliminated.

The five classes of planes required for the Navy are training, fighting, gunnery observation, three purpose, and patrol. Each of these classes has one or two service-types and most classes have several experimental types. The uses and features of these various types are briefly described and the development of powerplant accessories is outlined.

Slots at the leading edge and flaps at the trailing edge, which reduce landing and take-off speeds in experiment, will be especially valuable in deck-landing airplanes when they are fully developed. Torque-equalized brakes are being developed for these planes.

Reduction of resistance is being studied by making various parts retractable, by improving the sections and profiles of other parts and by developing cantilever wings.

Adjustable-pitch and reversible propellers are desirable but offer mechanical difficulties. Provision for floating wheel-type airplanes in case of forced landings on water is being made.

THE demands made upon naval airplanes of all classes are continually becoming more exacting. They must carry more and heavier bombs, machine guns, ammunition, and radio sets. They must go faster, climb higher and be able to remain in the air longer. They must be designed for minimum structural weight, yet they must be sturdy enough to withstand landings and take-offs in heavy seas and to ride out storms at buoys. They must be braced against the high acceleration of catapulting and the deceleration of deck landings.

The airplane must be easily maneuverable, must have a minute turning-circle, a quick take-off, and a slow landing-speed. It should go into a spin easily and come out of its own accord. Its stability must be sufficient to fly "hands off," yet it must answer its controls with lightning precision. The space allowed each member of the crew must be ample for comfort, and vision should be unobstructed in all directions. It must be possible to crash the airplane without injury to personnel. There must be reinforcements here and braces there so that heavy-footed mechanics may clamber about the plane without damaging it unduly.

Requirements of Various Types

The bomber must have all his instruments arranged in orderly fashion, readily accessible, behind a glass window fitted with a windshield-wiper. All bomb and torpedo-release mechanisms must be operated by electricity, yet there must be a separate system, operated by hand, in case of failure of the electric devices. The plane should carry parachute flares, landing lights, smoke bombs, baggage of the crew, emergency rations, anchor and line, engine tools, and spare parts.

The wings should fold to permit ready stowage aboard ship, and must permit of rigging for flight in 3 min. When rigged the total wing-spread must not exceed the dimensions of the elevators used to hoist the plane to the flying-deck of the carrier.

The hull or floats must not soak up water excessively, even when anchored for an entire season, yet if we make them of metal there should be no corrosion. The internal structure must be so thoroughly protected that corrosion will not take place even in tropical climates.

The powerplants, by which we mean not only the engines and propellers but also the fuel, oil and water systems with all tanks, pumps, piping, coolers, and heaters, must fulfil not a few requirements also. The engine should weigh not over 1¾ lb. per hp., yet be rugged enough to run 300 hr. between overhauls without breakdown, and a large percentage of this operating must be done at nearly full power. The fuel, oil and water pumps must be light, compact and reliable. The propeller must be thin enough to be light and efficient, yet must withstand the attacks of spray and rain. The fuel and oil tanks must be able to withstand the constant vibration without leaking, must be of a material not affected by benzol or ethyl fluid, yet cannot be of copper or tinned iron because these are too heavy. We must have a device for heating the oil quickly after starting, yet at the same time we must keep the oil cool in flight. We must have a radiator of lightest design, yet leakproof. It must be located for best cooling, but at the same time must not interfere with vision nor cause undue air resistance nor be a menace to the pilot in a crash.

From these random comments it is obvious that the design and construction of Navy airplanes and their powerplants consist of a series of compromises, probably

[1] Construction Corps, Naval Air Station, San Diego, Cal.

even more exacting than required in usual engineering practice. I shall attempt to mention some of the ways in which the Navy has met this situation in the classes of airplane now considered service types and to touch briefly on the lines along which development will probably tend in the near future.

Structural Elements

I will take up first the airplane structure, in which are included the hulls of flying-boats and the floats of seaplanes. Progress is being made along three principal lines: aerodynamics, structure and suitability for the purpose intended. The first two lead to better performance, safety and durability, and the last to greater usefulness as military weapons.

In aerodynamics we have reached a stage where the conventional refinements are chiefly in details and in ingenious arrangements of wings, control surfaces and their bracing. A few new and more efficient wing-profiles are being designed, but the progress is chiefly toward restriction of the travel of the center of pressure of the wings as the angle of attack changes. Effort is now devoted to reducing the parasite drag of the non-lifting portions of the airplane. The result of this is particularly evident in the fighting planes, which are models of "streamlining." However, we are apparently about to

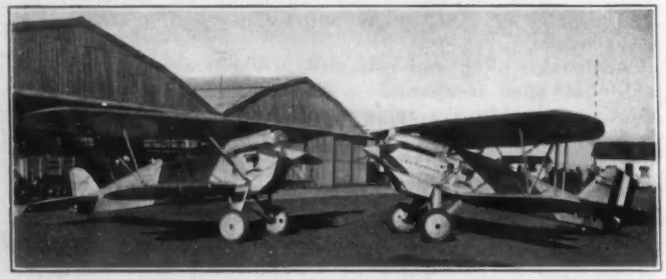


Fig. 1—Service Types of Fighting Plane
These Are Single-Seat Machines of High Performance. Improvements Are Being Made in New Planes Equipped for Use on the New Airplane-Carriers

enter upon a period of widespread adoption of slotted wings and other aerodynamic developments which have, until recently, been considered highly experimental.

Ease of control and efficiency of control surfaces have advanced rapidly, and the maneuverability of all classes of airplane is receiving much attention. In even the large flying-boats the modern wings, the reduced spans and the improved control-surface arrangements have led to ease of operation and excellent response to control, together with small turning-circles in flight, which are the real tests of maneuverability.

All-Metal Planes Yet To Come

Structural design has progressed gradually from wood toward metal, though there are as yet no all-metal airplanes among the service types of the Navy. Fuselages of nearly all small and medium types and the hulls of large flying-boats are now of metal. These structures adapt themselves readily to metal, and the lessened danger to personnel from fire and splintering has encouraged the abandoning of wood. The earliest metal fuselage-frames were of mild-carbon-steel tubing, with gas-welded joints. This type of construction persists in the majority of fuselages, but the mild carbon-steel is being replaced by chrome-molybdenum steel. This alloy is used in a comparatively low-strength condition of 95,000 lb. per sq. in. ultimate, but even this is a distinct gain. The material has the additional advantage that it welds most satisfactorily. There is, however, a tendency to eliminate designs involving welding and to substitute any of the various forms of clamped, riveted or swaged and machined fittings and connections. Tubing is, naturally, still the usual form of frame member.

Duralumin is slowly replacing steel in non-welded structures. This alloy of aluminum has a definite weight-advantage over steel of all kinds except in a few specially restricted locations. The experience of the Navy with corrosion of duralumin has been very discouraging, however, and its adoption for principal structural members has been greatly retarded thereby. The experimental development of large flying-boats has brought out hulls entirely of duralumin, but there still exists some skepticism as to the length of service life these will have and as to the cost of upkeep.

The service-type wing is constructed with box beams of spruce and mahogany and truss ribs of spruce and plywood. Fabric is still the standard covering-material. The adoption of metal in the wings has been delayed by the difficulty of designing and fabricating wing beams and ribs of satisfactory weight-to-strength ratio, by the excessive cost of such construction in small quantities and again by doubt of the resistance of duralumin to corrosion. One service type incorporates wood beams and duralumin ribs, thereby solving the cost problem. Several sets of these wings are now under overhaul at San Diego, and a considerable amount of serious corrosion has been found where the duralumin has been in contact with salt water.

The control surfaces of most types are constructed of metal, either of duralumin channels and other shapes, of welded steel-tubing, or of a combination of the two. In these members, also, great care must be taken to provide adequate means of drainage, most thorough painting and easily accessible inspection openings.

Corrosion a Great Problem

Several attempts have been made to introduce all-duralumin floats, but thus far few successful floats have been produced and no service type includes them. Here, again, corrosion has been the drawback, with even more seriousness than in the wings. In view of the saving made possible by duralumin floats, in initial weight and in weight after water service, the lack of success with them is very regrettable. It seems certain that this problem will be solved in the near future.

Several airplane manufacturers are incorporating large numbers of aluminum-alloy castings, heat-treated to a tensile strength of about 28,000 lb. per sq. in. These castings are replacing many of the complicated and expensive fittings formerly built up of sheet steel, welded and brazed together. The lightness of the alloy permits sufficient thickness in these castings to obviate any doubt of their reliability or fear of failure due to flaws. Apparently they do not suffer from corrosion so seriously as aluminum-alloy sheet. They do not save much weight, but they do reduce the cost greatly. As foundry technique improves, the extra thickness now used as a "factor of ignorance" may be eliminated, with consequent weight-saving.

The forging of aluminum alloys has reached a stage of development such that the product is sufficiently reliable for use in aircraft. At present forgings are found only in propeller blades and in some engine parts, but we may look for their introduction in the airplane structure as soon as there are quantities of a single type to be made sufficient to warrant the cost of dies. After heat-

FIG. 2—THE LOENING AMPHIBIAN
Provided with Retractable Wheels, It Can Take-Off from and Land on Either Water or Land

treatment this forged alloy has the same strength as the sheets and shapes, 55,000 lb. per sq. in., ultimate.

The use of stainless steel naturally suggests itself in the discussion of corrosion of seaplanes. At present this material is very expensive, and somewhat unreliable in ductility and workability. The fact that it requires heat-treatment and polishing to be really rust-proof militates against its use in aircraft. It is being used today to a very limited extent. Doubtless its use will increase as the objections mentioned are eliminated.

FIVE CLASSES OF PLANE REQUIRED

The third principal line of progress, which I have called suitability for the purpose intended, has involved the development of five classes of airplane for the Navy. In each class we have one or two service-types, and, in nearly all classes, several experimental types. The five main classes are: training; fighting or pursuit; gunnery observation or short-distance scouting; the three-purpose plane for torpedo-dropping, bombing and long-range scouting; and patrol airplanes.

During the war and until 1924 all primary flight-training and elementary training in gunnery and bombing was carried out in airplanes designed and built in 1917 and 1918. These have now been replaced by two service-types, both of which are convertible for use either as land-planes or seaplanes. In either condition they can be used not only for flight training but also for gunnery and bombing practice, the latter with sub-caliber bombs. The properties of the ideal training-plane are fairly obvious. We have not secured them all in the present service-types, but have made progress toward the ideal.

In the fighting-plane class we have two service-types of single-seaters of very high performance, with excellent gun-power and in nearly all respects eminently satisfactory airplanes. These are shown in Fig. 1. Still further improvements are being made in the fighters now under construction; these comprise increased fuel supply, better powerplants, better vision for the pilots, landing gears better suited for deck landings, slightly slower landing-speed, and higher top-speed. These fighters will be used on the new airplane-carriers and are equipped for this purpose.

FIG. 3—THE THREE-PURPOSE PLANE
Wheels Can Be Substituted for the Floats Shown. These Planes Are Used for Torpedo Dropping, Bombing or Long-Range Scouting

The gunnery observation or "spotting" planes are used chiefly as seaplanes, launched from the catapults on the battleships. They are two-seaters, powered by air-cooled engines, and are of strictly conventional design. They are very popular with pilots, due to their excellent controllability.

AMPHIBIAN AND CONVERTIBLE PLANES

In the observation or short-range-scouting class is the Loening amphibian, shown in Fig. 2, one of the outstanding developments of the last few years. This airplane has wheels retractable into a seaplane hull. It can thus be used from an airplane carrier and be free from the menace of destruction in case of engine failure at sea.

FIG. 4—A PATROL PLANE
This Is a Two-Engine Flying-Boat for Long-Range Work

It is fitted with an inverted engine, which raises the propeller well clear of the water. Its performance is equal to that of the war-designed DeHaviland powered with a similar engine, and it is superior in cruising range.

The three-purpose class, Fig. 3, is composed of large single-engine planes, convertible from land-planes to twin-float seaplanes and suitably reinforced for catapulting and deck landing. These airplanes are used for torpedo dropping, bombing or long-range scouting. In the last-named duty the load-carrying capacity ordinarily devoted to a torpedo or to bombs is utilized for the large fuel-supply required. This type is being constructed in large numbers under recently awarded contracts. The new planes will have excellent arrangements for bomb sighting and releasing and for the comfort of the bomber. An ideal radio-room has been provided. The pilot's seat is located with particular regard to vision for deck landings. The performance of these planes will be much superior to that of the existing ones, in both speed and climb, due to the use of the new Packard 800-hp. engine.

The patrol planes, Fig. 4, are twin-engine flying-boats, that is, seaplanes in which the crew, fuel and useful load are housed in the hull. Their useful load consists of radio, several machine-guns for defense purposes and a large quantity of fuel. Their functions are extremely long-range searching for an enemy fleet, convoy duty as submarine lookouts, and similar missions requiring extended cruising. This type has been developed in a steady series of steps, each step representing improvements in structure, seaworthiness and powerplant, and increase in useful load and range.

Powerplant Accessories

The numerous airplanes very briefly described have required a parallel development of engines and all powerplant accessories. This progress has led toward lightening of all engines, a continuous rise in power and an improvement in reliability and ruggedness. In the endeavor to increase power-output the number of engine revolutions has been greatly increased until 2400 r.p.m. has been reached in fighting planes. This rate of propeller revolution is efficient in a high-speed airplane, but is entirely unsuitable for any other type. The best propeller-efficiency is obtained when the airplane speed is approximately one-third of the tip speed of the propeller. With rates of revolution of over 2000 per min., and with the large propeller-diameters required in large airplanes, the ratio of airplane speed to tip speed becomes as 1 to 5 or 1 to 6. To obviate this, the natural solution is reduction gearing. Such gears present a serious mechanical-engineering problem which has not been solved satisfactorily, though great progress has been made and several gears are in experimental use in the patrol-type planes. The usual reduction-ratio is 2 to 1.

Another problem is that of maintaining engine-power in the rarified atmosphere at great altitudes where Naval airplanes must operate in future warfare to escape anti-aircraft fire. The solution is supercharging, and several types of supercharger are being developed. Many of the service engines use rotary induction and distribution of the mixture, which is, in fact, low-pressure supercharging. This is effective only to moderate altitudes, however, and the high-pressure type must be perfected. Proper supercharging increases the ceiling of an airplane about 40 per cent and its speed at an altitude of about one-half the ceiling height will be increased at least 20 per cent.

An important advance in performance and reliability was made with the adoption of metal propellers. The Navy's definite policy today is to buy none but metal propellers. The prevailing type of propeller consists of a machined chrome-vanadium steel hub and detachable blades of the forged and heat-treated aluminum-alloy already described. These propellers are more efficient than those of wood, are more reliable in strength and do not deteriorate with age. Experiments are now being conducted with blades of an alloy of magnesium which weighs only two-thirds as much as aluminum and appears to be amply strong for certain types of propeller.

Experimental Progress Outlined

I have touched briefly on the present developments. There are many experiments in progress, and there are more proposals that have not yet reached the stage of experiments. Many of these are of interest, as they will probably appear, in refined and altered forms, in the aircraft of the next 5 years.

In the field of aerodynamics, several fairly radical developments can be expected. The problems of control below stalling speed, or minimum speed required for flight under ordinary conditions, and of greatly reducing the landing and take-off speeds, which are intimately connected, will probably be solved by the more general adoption of wings with slots at the leading edge and flaps at the trailing edge. These devices, which increase the lift of wings at very high angles of attack, have been operated experimentally with some success, and when they can be installed in service airplanes without the present undue complication and excessive weight they will be favorably received. They will be especially valuable in deck-landing airplanes by reducing the hazards to personnel and the high stresses in the structure incident to the feat of landing and stopping present-day fighting-planes on the small deck-areas available.

In addition to aerodynamic means of reducing run after landing, many experimenters are working on mechanical brakes for the wheels. Several commercial-airplanes have been so equipped and have used the brakes with entire success. The Navy has under development a design for torque-equalized brakes which will cause the airplane to run straight automatically, yet will permit the pilot to steer it by the rudder-bar. The brakes are initially set by hand.

Reducing Resistance

When the practicable limit has been reached in detailed refinement to reduce resistance, resort may be had to making retractable various portions of the airplane which offer great drag and no lift. Such are landing gears, which will be drawn up into the fuselage or wings, and the wing-tip floats in seaplanes, which may be swung into line with the tips of the wings, thereby being "faired in." The radiator, instead of being shuttered, may be made partially retractable within the fuselage.

Another possible means of reducing drag in seaplanes is to design the floats with lines offering less air-resistance. Attempts at this are already being made in the form of rounded bows and transverse sections without sharp corners. This may eventually result in floats of circular section, fitted with fins of profile similar to that of wings, to secure stability and the necessary planing effect on the water.

In shipboard airplanes the designers are restricted by lack of stowage and handling space to the biplane arrangement of wings. In patrol planes which operate from shore bases the larger span of the monoplanes is not objectionable, and the tendency is to develop them because of their greater aerodynamic efficiency. Further reduction in resistance will be realized with the incorporation of cantilever wings, eliminating the high drag due to struts and wires. This trend offers inviting possibilities in biplanes also, and in them it is especially valuable. The structural and maintenance difficulties are considerable, but can be overcome; as will also the psychological difficulties with the operating personnel, who naturally prefer airplanes fitted with visible means of support between wings.

As the size and weight of flying-boats for patrol service increases, the designed load per unit of wing area must increase to maintain high speed and because the percentage of structure weight to total load can thus be reduced. The high wing-loading increases landing-speed and length of run for take-off, but in large flying-boats these are not serious. The Naval patrol-plane of the future will probably be a three-engine monoplane, of all-metal construction and with cantilever wings, on which the wing loading will approach 20 lb. per sq. ft. This plane will be able to remain in flight at full load on any two engines.

Power Control Will Be Needed

The effort required to operate the controls of large airplanes is fast approaching a magnitude beyond the pilot's muscular capacity. The present means of reducing the required force is to increase the distance moved by the control stick, wheel and rudder-bar for a given angular movement of the control surfaces; that is, to increase the pilot's leverage. There comes a time when the movement required in the cockpit is so great that

there is not sufficient space available for the swing of the control column and the large control-wheel. The reduction for aileron movement becomes so great that several complete turns of the wheel are required to produce full aileron-throw. The solution of this will be control operation by motors, much as the steering-gear of ships is now operated.

The greatest promise of increased efficiency lies in improvements in details of structural design to decrease the weight of the flying structure and to increase its dependability and durability. It has been proved that all-metal construction reduces the weight of the structure 15 or 20 per cent. It seems indisputable that all airplanes will soon be of metal construction. The present great drawback, susceptibility to corrosion, must be removed, particularly for duralumin. The process developed by Vickers in England, known as "anodic treatment," is of great interest. This is an electrolytic process which deposits on the surface of the duralumin a closely adhering coat of aluminum oxide, which is the best-known corrosion-preventive for aluminum and its alloys. This treatment of duralumin will, it is believed, dispel the doubts which now retard metal construction.

Structures will be much simplified and lightened by the adoption of the stressed-skin principle for wings and fuselages. At present the frameworks carry the entire load, and the skin is of doped fabric. With a stressed skin all the valuable qualities of steel ships will be secured to airplanes. The material of all parts in contact, including the rivets, will be identical. There will be no galvanic action, resulting in the entire ruin of the duralumin, such as occurs when steel and duralumin are in contact.

Supercharged engines, to maintain power when operating at great altitudes, have been mentioned. These introduce a serious problem in propeller design. A propeller that will allow an engine to deliver the proper number of revolutions near the ground will allow it to turn entirely too fast in rarified air, so that the operation of this engine would become unsafe at very great altitudes. On the other hand a propeller large enough to hold the engine to a safe speed at great altitude will reduce the speed at the ground to such an extent that the airplane will not take-off.

Adjustable and Reversible Propellers Needed

The solution seems to be a propeller of adjustable pitch to permit keeping the rate of revolutions constant. This device is simple from the aerodynamic viewpoint, but the mechanical engineering is difficult in view of the very high disruptive forces exerted on the central portion of a propeller and of the necessity for ease of adjustment by the pilot.

An extension of the principle of adjustable-pitch propellers produces the reversible type, in which the direction of thrust is reversed by a sufficient adjustment of the blades. This feature, if applied just at the instant of landing, will bring an airplane to a stop in one-third of the distance ordinarily required. The adjustable and reversible propellers, when properly developed, will combine to add appreciably to the value of our fighters and bombers, which, in addition to performing at great altitudes, are required to land on the carriers' decks. It will be seen that there will be available three means of shortening the run of an airplane after landing. All of them require operation by the pilot and it is therefore probable that not all will be fitted to any one airplane.

The excessive air-resistance and weight of the radiators for the large water-cooled engines have led to consideration of steam-cooling for aircraft. This system presents very attractive possibilities, particularly for seaplanes, in which the floats could be used as condensing containers for the vapors. Small water-reservoirs, connected with the engine-cylinder jackets and the floats by pumps, would complete the equipment. This device has not been attempted as yet, but has been proposed by at least one designer of racing seaplanes and considered seriously. In this particular design, which incorporated an 800-hp. engine, calculations showed that 300 lb. would be saved by using steam-cooling.

It is not difficult to prophesy general developments of the near future toward making the airplanes of the Navy more useful as military weapons. The aviation branch is an integral part of the Navy, and must go to sea with the fleet, either on ships or in the air. The planes to operate from aircraft carriers will be the fighters and bombers on wheels and the amphibian scouts. The patrol, torpedo and spotting planes will continue to operate as water-landing aircraft. The spotters will operate from catapults on battleships and cruisers, as at present, and will be protected by fighting seaplanes carried on the same ships.

Future Developments

The tendency in all water-landing aircraft is expected to be to abandon the float type, now known as "seaplane," in favor of the hull type or flying-boat; because of the inherently better seaworthiness of the latter. Torpedo planes will be flying-boats large enough to carry one torpedo on each side of the hull or to house one in the lower part of the hull on the center line. The patrol planes will be fitted with telescoping masts, so that sails can be rigged in case of forced descent far from land.

The present three-purpose-type airplane will probably be superseded by three distinct types as numbers of aircraft in the Navy increase. No airplane that must be equipped for carrying out any of three functions can be as efficient at any one of them as can a single-purpose plane. The scouting will be done by amphibians of long range, the bombing by land-planes of good climb and ceiling and the torpedo-launching by flying-boats of high speed. The twin-engine type will probably be adopted for bombing, as it allows a better arrangement than the single-engine type for the bomber's vision and efficiency.

A new type recently put into production, the high-performance two-seat combined fighter and observation plane, will be developed for carrier use and also for the battleships, probably replacing the present gunnery-spotters and the fighters that protect them.

A question of safety occurs to all of us when considering the operation of airplanes with wheel landing-gear over the ocean, many miles from their base of action, which is the carrier. A forced landing of one of these planes is final unless the pilot is very soon picked up. The Navy is taking the natural step to remedy this by installing flotation gear inside the fuselages of all planes having wheel-type landing-gear. In addition to providing this buoyancy, the fuselage bottoms are V-shaped, to ease the shock of a water landing and to reduce the probability that the plane will capsize or expel the occupants by the force of the impact.

Naval aviation is still in its early youth, and the multitude of problems is barely beginning to be solved. We have, however, secured enough aircraft to commence training ourselves along the lines of action we think we would follow in time of war, and we have inaugurated a program which at the end of 5 years should place us in a satisfactory state as to both materiel and personnel.

Airplanes for Commercial Aviation

By A. H. G. Fokker[1]

Metropolitan Section Paper *Illustrated with* Photographs

COMMERCIAL airplanes are always a compromise. Speed is a very important factor, but speed alone is not what they offer to passengers; they offer safety and comfort in the form of roomy cabins equipped with all the necessary things that are provided by railroad trains, a good heating system, a good ventilating system, glass windows that can be opened and closed, and an aisle with room to walk between the chairs. In large airplanes it makes no difference whether all the passengers are on one side or a few are in front or in the rear; but large cabins cause more air resistance and sacrifice speed.

We have built airplanes that have flown faster than 300 m.p.h., but their dimensions are small and they carry no pay-load. Large commercial airplanes have more horsepower and less speed; they are a compromise because they must be built to endure hard work, to make many landings a day and to last for several years.

The life of an airplane should be at least 2000 hr. We guarantee our airplanes for at least 2000 hr. in the air, with no considerable amount of repairs or overhauling. We have some planes that have been in the air 3000 hr. and are like new.

Airplanes will take the same place in transportation that automobiles now occupy.

The cooperation that commercial aviation is receiving from the Army and the Navy in developing engines is very valuable.

The Air-Mail pilots deserve much credit that is not given them. A person who receives a letter by Air Mail does not appreciate what it has cost the pilots in nervous energy, knowledge and skill.

The success of commercial aviation depends upon safe construction to secure the confidence of the public.

Our Government furnishes the lights, maps and radio service to enable vessels that travel along the coast to complete their voyages safely; but it has not yet furnished the ground service needed by commercial airplanes.

Safety of Operation

The safety of operation of airplanes is not merely a question of construction, but of ground organization. Airplanes have been developed to such an extent that we can say that the machine itself is perfectly safe; at least, it is fully as safe as any vehicle operating on the surface. I never feel as safe in an automobile traveling 60 m.p.h. as in the air at three times that speed, not only because of the possibility of technical breakdowns, but because there are not yet so many fools in the air as there are on the ground.

For safety of operation, the first thing needed is a good system of weather reports. The pilot ought to know at the moment he starts what the weather is along the whole route. Besides, if there are changes in the weather, he should receive the information during the flight. If he starts from Philadelphia, with the knowledge that he can land in the City of Washington and that the weather is clear and fine, he ought to be advised by telephone, radio, or signals if the weather changes so that he cannot land there; then he can return or can make a landing at some other place.

To produce really efficient service in long-distance flying, a kind of block system, or a radio or telephone system, should be provided, so that the pilot can be communicated with at any moment and at any distance. Such systems are used on many of the airplanes crossing the English Channel between London and Paris, and between London and Amsterdam, where fog comes up very suddenly.

Night flying is very important and several problems are yet to be solved to make possible safe operation at night during periods of rainy or foggy weather and poor visibility, and when high mountains must be crossed, as by the Air-Mail pilots who fly from Chicago and from New York City to the Pacific Coast. With the machines and instruments at present in use, the pilots are doing remarkable work and they deserve much credit that is not given them because the public does not know about it. A person who receives a letter by Air-Mail does not appreciate what it has cost the pilots in nerves, knowledge and skill. We are developing instruments with which it will be possible for a pilot to keep his course and determine the position of his airplane in the air, even though the visibility is totally lost. When these instruments are available we shall be prepared for night flying on a large scale in commercial service.

Not alone the question of remaining in the air, but that of landing on the fields at night, is one of the greatest problems. Very clever persons now are concentrating on this problem. The air-line that has been operating since July 14, 1926, between the City of Washington and Philadelphia with three-engine airplanes has made a wonderful record for safety. It has carried more than 3600 passengers without a forced landing due to mechanical trouble, although a few landings have been made because of the weather and because not enough ground organization was available. A large part of the ground organiza-

[1] M.S.A.E.—Atlantic Aircraft Corporation, Hasbrouck Heights, N. J.; president, Fokker Aircraft Corporation, New York City.

tion will need to come from the Government. Our Government furnishes lights, maps and radio service to enable vessels that travel along the coast to complete their voyages safely; but it has not yet furnished the ground service needed by commercial airplanes.

Do not blame the new aviation Secretaries of War, the Navy and the Department of Commerce for this condition; they are ready to render that service, but are waiting for the money to be appropriated by Congress. If you feel the need of it, go to your Congressman and say, "You must appropriate the money so the aviation companies can give us service." We are ready with our airplanes; we are ready with our engines; we are ready with almost everything else; but we are waiting for the Government to give us air-navigation service.

Airplanes Must Not Be Overloaded

Besides the safety of airplanes, there are the questions of construction and of operation. One of the most important considerations in operating an airplane safely is not to load it to its maximum capacity. To operate safely, an airplane must maintain a certain reserve capacity to give safety in taking-off, and ability to remain in the air if one of the engines stops, where more than one engine is used. During the last few years we have improved these flying-qualities considerably. We are able now to build airplanes that will not fall suddenly or cause the pilot to lose control even though the airplane loses speed. If stalled in the air, a modern airplane will not go into a sudden uncontrollable nose-dive or tail-spin but will settle slowly on an even keel and the pilot can keep perfect control. So far as possible we have eliminated every danger in the air, and the greater stability has also increased the safety of taking-off and of landing.

Frequently you hear the claim that all-metal airplanes are the safest construction; that the all-metal airplane cannot burn. The fact is that the airplane itself does not burn, but the gasoline burns. If an airplane crashes with several hundred gallons of gasoline, the gasoline may burn regardless of the material of the plane. We have developed a gasoline system to make airplanes safe. We have located the tanks out on the fuselage as far as possible from the cabin, so that in case of accident the gasoline in the tanks will not be ignited.

Fig. 2—Interior of Cabin of Fokker Three-Engine Airplane
A High Degree of Comfort Is Possible and Ample Space Is Available for a Desk, Stenographer and Several Chairs

Cantilever Wings of Wood

Our fuselages are made of welded steel tubing covered with fabric. The wings are built entirely of wood, the main beams and ribs being covered with three-ply veneer, which has considerable strength in every direction. I have found out in 14 years' experience that wood is a very good material with which to build large cantilever wings, especially while airplanes are improving so much and the types are changing so rapidly. The engineering work can be done much more quickly, more easily, and more cheaply for wood than for metal.

A very important factor in the safety of airplanes is

Fig. 1—Fokker Three-Engine Airplane
This Airplane Has Flown Approximately 14,000 Miles about the Country

the location of the pilot, particularly so that he may have as good visibility as possible. We are trying, therefore, to put the pilot forward where he will have the least possible obstruction to vision. Many of the larger commercial ships have dual control, affording an opportunity to relieve the pilot in case of sickness or for any other reason, the relief pilot being able to take over the controls immediately.

Fig. 1 shows a three-engine Fokker airplane that has successfully flown about 14,000 miles around the Country. Fig. 2 shows the interior of the cabin, indicating the amount of space and the degree of comfort that are available in modern commercial airplanes. There is a room for a large desk, a stenographer and several chairs. The interior of these large airplanes can be arranged in many ways. Our latest type is an ambulance for the Army, which can carry six patients in litters and two doctors, leaving ample room to move about. All these planes are equipped with lavatories, running water and other conveniences.

Besides the three-engine airplanes such as are in use on the regular air-route between Philadelphia and the City of Washington, we are building single-engine ships, one of which is shown in Fig. 3. These are of smaller size and are very economical. The primary purpose of more engines is to secure a larger factor of safety in operation.

Use of Brakes on Airplane Wheels

The latest development in commercial airplanes, first in our larger planes and more recently in the smaller planes as well, is the use of brakes on the wheels. We used to land at a speed of 80 or 90 m.p.h. and allow the planes to roll until they came to a stop. It is strange that we should have waited so long before using brakes, because they are one of the most necessary things in airplanes. In the very near future every airplane will be fitted with brakes. The type of brake used is very much like an ordinary automobile-brake, the difference being that the construction is lighter and refined to the extent necessary in airplane work. The brake is of the internal-expanding type, fitted entirely into the wheel so that only the operating cable to the lever is visible. This enables the pilot not only to brake the airplane on the ground but also to steer it on the ground by operating the brake on either wheel independently.

In our three-engine airplanes we have made it possible for each engine or all engines to run on any fuel tank, and the pilot can see how much gasoline is in each tank. We prefer level-gages such as are fitted to steam boilers rather than mechanical gages.

You have probably noticed that after an airplane comes in, the tail is lifted and it is carried off the field, either by men or on a little car. The larger ships weighing several thousand pounds require so many men for this that we were forced to adopt a kind of lift-truck that works like a garage jack. This enables one man to handle the largest three-engine plane. We call it a "one-man dolly."

Single Versus Multiple-Engine Airplanes

One thing I particularly wish to explain is the reason we use more than one engine in our large airplanes. As in other forms of transportation, safety and reliability can be obtained only at the expense of greater operating costs and, therefore, of reduced profits. In the airplane this can be translated into powerplant reliability at the expense of pay-load.

Present aircraft engines are probably more reliable, all things considered, than almost any other form of powerplant. However, failure of the powerplant in an airplane is a matter of greater importance than it is in other forms of transportation. The obvious remedy is to increase the number of engines in an airplane so that failure of one unit will not involve a forced landing. The airplane carries on, at possibly reduced speed, until it reaches a suitable landing-field, or even to the end of its journey. Now, what is the cost of the increased reliability thus obtained? If two engines are used, the failure of one of them places the burden entirely on the other, which accordingly has to be powerful enough to fly the airplane alone. In the case of three engines, the failure of one reduces the available power by only one-third; with four-engines, one-quarter, and so on. The smaller the number of engines used is, the larger they must be to maintain flight under conditions of emergency. Furthermore, the larger they are the greater is the proportion they represent of the gross load of the airplane, with consequent reduction in the volume of pay-load that is carried.

The success of commercial aviation depends largely upon safe construction to secure the confidence of the public. Before regular airplane-transportation service is available across the Atlantic, we shall be obliged to guarantee the safety of those airplanes. We shall not be able to build and use the most economical planes for long-distance operation, because we shall need to sacrifice a certain amount of economy for the sake of safety. In the end, the increase in passengers and freight carried will offset this increase in the transportation cost.

Future of Aviation Depends on the Engine

What the future of aviation will be is very difficult just now to say. It is difficult to say how large airplanes will be, whether in the next few years we shall produce planes for 50 passengers or for 100 passengers. That will depend on how the engines develop. Builders of airplanes are looking forward to further development of engines.

The cooperation that commercial aviation is receiving from the Army and the Navy in developing engines is very valuable, because the Army and the Navy are the only customers of engine builders who are able to pay the money necessary for the development of the engines; and every development that is made for this purpose benefits commercial aviation. Therefore, it is well that this close cooperation has been developed during the last few months among the Departments of War, Navy and Commerce; and we certainly appreciate it in the industry.

Many times I have been asked if the time will come when everybody will have his airplane just as we have our automobiles now; and what is the type of airplane that we shall have in the future? I can answer only in this way: Just as we have automobiles of various sizes and powers for different purposes, so we shall need to develop airplanes of various sizes. Aviation is a very large and most fascinating field. One of the main reasons that many of the younger men are eager to enter aviation is that it offers an unlimited opportunity for organization and for inventive brains in developing commercial aviation to the point at which the automobile industry is now. Airplanes will take the same place in transportation that automobiles now occupy.

THE DISCUSSION

Lieut-Col. B. D. Foulois[2]:—All of us, especially those who are connected with the National defense, are looking forward to the development of commercial aviation.

[2] A.S.A.E.—Air Service, Mitchel Field, Hempstead, N. Y.

FIG. 3—SINGLE-ENGINE FOKKER AIRPLANE
This Airplane Is Smaller than the Three-Engine Type and Is Very Economical

Without it we cannot expect to have the sort of airplane industry in this Country that will be needed for the military and naval air forces. We are heartily in sympathy with those who are putting commercial aviation on a paying basis and are willing to work with them at all times.

CHAIRMAN ALEXANDER KLEMIN[3]:—Commercial aviation is not altogether a matter of transcontinental service and passenger-carrying over long distances. More of it than we appreciate consists in a variety of services such as instruction, carrying of films, miscellaneous passenger-services, aerial photography, and the like.

C. S. JONES[4]:—Knowing that some of the New York City newspapers did not intend to send their own reporters to cover the last Ford Air Tour, I went to the editor of one of them and offered to prepare some articles upon it. The editor said:

> The Ford Tour has reached a stage where it is no longer news. We are not sending our own men because we do not consider it news that a few airplanes fly from city to city and arrive on time.

When we remember that only a short time ago any kind of a flight was regarded as front-page news and then consider that 27 airplanes started on the Ford Tour of approximately 3000 miles, that there were no serious accidents and that 24 of them completed the tour, we realize something of the advance in aviation.

OVERCOMING PLUMBING TROUBLES

CHAIRMAN KLEMIN:—Mr. Fokker pointed out that the further advance of commercial aviation depends largely on the engines. I understand that at least 40 per cent of the forced landings in the British Air Service are due to the engines and that a large number of the failures are failures of the radiator and the water-cooling system. Fortunately, we are overcoming those difficulties. On Mr. Fokker's ships we find air-cooled engines and no radiators.

G. J. MEAD[5]:—Ever since we have been building airplane engines we have been told that if the engine builder would only produce a suitable engine the airplane would be all right. The engines with which we were familiar at the end of the war would run wide open only about 10 hr. Present engines will run at least 300 hr., so a commercial company can probably operate most of the season without any overhauling except perhaps a top overhaul, which is very simple in the case of an air-cooled engine.

It is not so much the design of an engine as the quantity of its production that reduces its cost. With the Government services using power units suitable also for commercial purposes, the combined quantity will bring the prices down. That is now evident in the 200-hp. class.

[3] M.S.A.E.—Professor of aeronautics, Daniel Guggenheim School of Aeronautics, New York University, New York City.

[4] Service and sales manager, Curtiss Flying Service, Inc., Garden City, N. Y.

[5] M.S.A.E.—Vice-president, Pratt & Whitney Aircraft Co., Hartford, Conn.

UTILIZATION OF ENERGY

MODERN civilization is sharply differentiated from civilizations that have preceded it by the incomparably greater extent to which it utilizes energy. For this energy it depends chiefly upon the various forms of fuel. Two pounds of coal will develop as much energy as a man at heavy labor for a day. The industrial status of a country is, therefore, largely determined by the supply of energy available to the individual worker. Nowhere is this supply comparable to that afforded in the United States. While the white population of the world increased about 3 times from 1815 to 1914, the production of mineral fuels, coal, oil and natural gas, increased 75 times; and by far the largest proportion of this increase has been in our own Country.—From an address by Arthur D. Little.

Cast Iron in the Automotive Industry

Discussion of E. J. Lowry's Annual Meeting Paper[1]

CAST iron is purchased on a basis of price instead of quality, according to the author, who says that this has depreciated the qualities of the material generally and caused engineers to look askance at its application. Combined with such factors is the influence of misinformation about cast iron that has been widely broadcast. Questions regarding the design of patterns and cheaper raw-materials have involved the foundrymen in controversial discussion concerning the influence of various elements to the detriment of the economic condition of the iron industry as well as that of the consumer of castings.

Due to the lessening of the consumption of cast iron, the foundry world has inaugurated research to better the quality of cast iron, not only through investigations of raw materials but also by improvement in melting practice. Although the accomplishment thus far attained has been small, the future outlook is that, due to the application of the results of research or by the use of alloys, the field for cast iron will become broadened. Then the engineer can obtain the material suitable for his needs and the foundryman will have a metal with the requisites suitable for foundry work.

The work of the metallurgists—microscopic, chemical and physical—has resulted in data which may help in overcoming previous prejudices. Some of the undesirable elements have been eliminated to overcome difficulties in casting, and yet this has been to the detriment of the physical qualities of cast iron; but when their proper relativity has been determined these elements will find their way back into the iron and better qualities will result.

The data presented tend to prove that true hardness is not measurable by any known test. Further, that the present hardness-test is not a function of machinability or of wear and that combined carbon bears little relation to any of these three factors. The governing features seem to be the forms of carbon, structure of the iron and quality of the materials used.

The method used in determining quality of material is that of dilatation. This test showed that the expansion of the casting is related to the expansion of the material used. It is felt that continual experimentation with this method will enlighten the many unanswerable questions which arise concerning cast iron at present.

Points brought out in the discussion of the paper include references to the variation in degree of "expansion" of cast iron, the effect of reheating and of high phosphorus-content on "growth," the effect of lowering the content of silicon, and considerations regarding hardness. The influence of carbon is discussed also, as to the total amount present, the amount of carbon in its combined state and its micrographic structure. The inadequacy of checking the quality of cylinder-block castings by the physical properties of a test-specimen is stated, and the reasons are cited.

QUESTION:—Is the expansion of cast iron necessarily undesirable?

E. J. LOWRY:—Expansion does not accompany hardness. One would assume that, in a white-iron casting having a high percentage of combined carbon, the amount of combined carbon would be reflected in the expansion; but that is a minor effect only. Expansion is governed more by the amount of silicon present than by the combined carbon. Expansion is undesirable unless the two materials that are expanding do so at equal rates. The degree of expansion of castings derived from several different sources varies and may vary in the castings from a single source. Consequently, unless the degree of expansion is uniform, the life of the iron and its machining qualities are different. Also, the amount of tolerance or clearance normally allowed in engine design is varied by the fact that the irons used in the assembly of the engine would be different.

QUESTION:—When the iron is heated the second time after casting, is the curve different from that obtained when it is heated the first time?

MR. LOWRY:—Cast iron grows on being heated; so, the points of beginning and ending of the curve are different but the general characteristic of the curve remains the same. Even when the piece is heated and quenched and then reheated, the characteristics are the same. This fact can be used as a means of measuring growth. By continued reheating, one can determine the actual growth of the cast iron because of the fact that continued heating does not change the characteristic; or, the cast iron can be heat-treated and its normal characteristic determined, allowing for the growth that takes place in the first heating.

QUESTION:—Is not part of the increase in expansion due to the annealing-out of the combined carbon which would occur in the first heating and not in the second heating?

MR. LOWRY:—As I said, combined carbon seems to have no fundamental effect on the curve, no basic function, although it does have an influence because of the heat energy involved in throwing the combined carbon into and out of solution. Comparing two specimens, one having high and the other having low combined-carbon content, both seem to be influenced more by the silicon present than by the combined carbon.

QUESTION:—Does open-grain structure of cast iron increase its wearing quality by holding the lubricant better?

MR. LOWRY:—It is supposed that the open-grain structure does hold the lubricant and thus prevent wear, and it is also supposed that the graphite, being large, forms a lubricant in itself, thereby affording an opportunity for an amorphous filament to be formed in the cylinder-bore which prevents wear. In the tests we made, we kept water on the specimens. The maximum temperature obtained was 212 deg. fahr. Each one of the specimens was put on a rotating rod and changed in position so that it would get the same relative wear due to outside influences.

[1] The paper with illustrations was printed in the February, 1927, issue of THE JOURNAL. The author is metallurgist for Hickman, Williams & Co., Chicago.

Control of "Growth"

QUESTION:—What analysis of iron, or what way of treating it, will reduce "growth"?

MR. LOWRY:—Growth does not seem to be a function of analysis. We reheated four different specimens of like analyses 100 times each and got four different degrees of growth. What actually happens is that after a certain point is reached the carbon begins to oxidize out. The carbon is oxidized even to the center of the specimen and small pockets are formed where the carbon originally was. I know of no analysis that will show anything about growth. It is a matter of getting the material that has the least degree of expansion to start with, and by that means getting the least amount of growth, which is practically a function of metallographic analysis rather than one of chemical analysis.

QUESTION:—Is growth of cast iron due to the oxidation of the carbon in the graphite?

MR. LOWRY:—I do not say that growth is due to oxidation, but that is what actually takes place. There are certain stresses within the iron and, since the grains of iron have a tendency to have their axes in the proper direction, they turn until their axes assume the right position. Next, heat begins to attack the carbon and to burn it out. That was verified by an English metallurgist.

QUESTION:—What relation has permanent growth in cast iron to high phosphorus-content?

MR. LOWRY:—High phosphorus-content lessens the initial growth, and the growth decreases with continued reheatings. The first heating gives the maximum growth. After 100 heatings, hardly any growth can be detected.

QUESTION:—With a high graphitic-carbon content, is not the permanent growth much greater?

MR. LOWRY:—Not necessarily so. That is not borne out as well in practice as in theory. With a high graphitic-carbon growth having a normal iron-matrix, the carbon has its greatest accidulated form; therefore, the carbon does not make the casting grow if the iron matrix is normal, because there is nothing to make it grow.

QUESTION:—How about lowering the silicon content?

MR. LOWRY:—One must keep within practical limits. If the silicon content is reduced, it must be replaced with some alloy like nickel that does not cause expansion but does have the same effect as silicon.

Degrees of Hardness

QUESTION:—If the hardness of the cylinder-wall is lessened, what is the effect on the cylinder-wall if the hardness of the outside of the piston-rings remains the same?

MR. LOWRY:—The hardness of the two must be correlated. At present, piston-rings are of one composition and cylinder-walls are of another. The former average from 0.40 to 0.60 per cent of phosphorus and the cylinder-walls from 0.18 to 0.23 per cent. That percentage of phosphorus in a piston-ring gives greater wear and less expansion. The silicon content in piston-rings averages 2.35 to 3.00 per cent. Cylinder-walls average 1.65 to 2.35 per cent of silicon, although some cylinder-walls contain 2.80 per cent of silicon. Due to the high content of silicon, the piston-ring has greater expansion than the cylinder-wall and wear is caused by the piston-ring.

QUESTION:—Under present piston-ring practice as regards hardness, would a cylinder-wall Brinell-hardness of less than 165 be advisable?

MR. LOWRY:—I prefer not to judge by the Brinell-hardness but to use the ultimate-strength in tension and compression as guides.

QUESTION:—Since the use of alloy in cast iron produces a greater amount of temper carbon, does not the use of phosphorus produce the same effect?

MR. LOWRY:—Temper carbon is the worst form of carbon in gray iron so far as machinability, expansion or hardness is concerned. A primary graphite, which is the crescent form, gives a Brinell-hardness of 160 and the secondary form, which is the round spotty graphite, also gives a Brinell-hardness of 160; but the former product has better machinability than the latter. I repeat that the right materials must be used. Then, alloys can be used to produce a better cast iron.

QUESTION:—Some plants use 0.90 per cent of phosphorus in some of their cast irons and 0.20 per cent in others. Is not that too great a difference?

MR. LOWRY:—Not with regard to phosphorus. The question relates to a cupola condition, I believe. Considering the silvery irons rather than the phosphorus irons, Victor Crosby, of the Studebaker Corporation of America, states that he gets uniform results, depending upon where he places the materials in the cupola.

Metallurgical Considerations

T. H. WICKENDEN[2]:—The impression I received from reading Mr. Lowry's paper was that it somewhat discredits the influence of carbon on cast iron. But I still believe that carbon has a greater influence on cast iron than has any other single element. The total amount of carbon present and the amount of carbon in its combined state tell part of the story, but not all of it; the micrographic structure of the carbon tells a large part. In a certain state, carbon may give a Brinell-hardness of 400 or 500; in some other state, it may give a Brinell-hardness of 120.

The metallurgy of steel is simple compared with that of cast iron. It is true that the same chemical elements are present, but many of them are found in greater quantity in cast iron than is ever tolerated in steel. The result is the presence of new micrographic constituents, all of which have their influence. The quantity and the character of these elements vary with the raw material, the method of melting, the temperature reached in melting, the temperature of pouring, the rates and conditions of cooling, and many other variables.

I agree with Mr. Lowry that the common method of hardness determination may be no indication of the machinability of a piece of iron. I have known an iron of 248 Brinell-hardness to be machined faster and with longer length of life of the tool than a similar casting having a Brinell-hardness of 160. An analysis of the iron showed the total amount of carbon to be the same and the amount of combined carbon to be not widely different. Microscopic study explained the difference. The microstructures were different, largely due to the condition of the combined carbon. The iron having the high Brinell-hardness, which machined the easier, showed a matrix practically free from excess cementite and the combined carbon was in a uniform sorbitic condition. This condition was produced by a proper addition of nickel to the iron. The iron having the low Brinell-hardness showed a matrix of lamellar pearlite in which was dispersed considerable excess cementite or carbide. These hard microscopic particles resulted in the quick dulling of the tool.

[2] M.S.A.E.—Development and research department, International Nickel Co., New York City.

The wearing properties of the iron having the high Brinell-hardness were much superior, as the iron having the excess cementite scored easily and seemed to tear itself to pieces. Mr. Lowry mentions wear tests on cylinder-blocks in which a soft open-structure iron wore better than a close fine-grained iron, but I am familiar with tests in which the opposite conditions gave the best results, where cylinders having a high Brinell-hardness showed superior wearing-qualities. Therefore, I think we must analyze more deeply before we have the final answer with regard to wear, as one test may show some one iron to be superior, while a similar test with different unit-pressures may show different results.

MR. LOWRY:—I did not intend to discredit the influence of carbon on cast iron in any way. I wished to bring out the varying opinions as to carbon being the controlling element in cast iron. Regarding wear, I agree with Mr. Wickenden that the many variables make it difficult to measure. We have not delved deep enough into the matter to determine one standard way of measuring. When we arrive at such a standard, I think the results will be in accord and that they will be very important.

PROPER USE OF RAW MATERIALS

ARNOLD LENZ[3]:—Not very long ago it would have been disastrous to take cylinder-block or cylinder-head castings out of the sand while at a bright-red heat. Today, under modern manufacturing methods, this procedure has become the rule rather than the exception, and this is done with a lower percentage of cracked and warped castings than was ever true before. Incidentally, this new quality of iron, which leaves the iron practically unaffected by severe temperature-changes, has also practically eliminated the danger of cracks in the finished engine. This has been accomplished with practically no change in the analysis.

The practice of checking the quality of the cylinder-block casting by analysis, or by the physical properties of a test-specimen is inadequate, because neither test will indicate the condition of the iron in the cylinder-bore. This is due to the slow cooling in the section enclosed by the water-jacket, which usually shows-up as being considerably softer than a test-specimen and, in most cases, also softer than a section below the water-jacket. I have practical proofs extending over a period of 2 years that the variation in the cylinder-bore can be overcome definitely by the proper selection of the raw materials, choosing them for their physical as well as their chemical composition. This same selection also will control the presence of hard spots, and the machining qualities in general.

The old theories on the effect of combined carbon, total carbon, silicon, manganese, and the like are proving inadequate in our advanced practice. The same analysis of iron that will show a transverse strength around 3000 lb. per sq. in. under one condition will increase to a transverse strength of 4000 lb. per sq. in. if treated according to our new theories and new methods. The uniformity in hardness and in machining qualities will show an equal variation.

Such variations in the practical results obtained from the application of the accepted theories has had a damaging effect on the foundry industry. It has cast reflection on the judgment of those engaged in the business and has put them at a disadvantage in dealing with engineers and designers who, very often, prefer the advice of a theorist to the findings of a practical man who has to meet the problems every day. This condition can be improved only by a closer understanding and an exchange of thought between the engineer, the designer and the foundryman.

[3] Assistant to the general manager, in charge of foundries, Saginaw Products Co., Saginaw, Mich.

SHALE OIL

ALTHOUGH research in regard to the extraction of oil from shale was as active in 1925 as in the preceding year, the actual production of shale oil was considerably less than the 600,000 gal. in 1924. The production for 1925 was reported from one plant in California, that of the N-T-U Co., which was built in 1922 near Santa Maria. The salient points of operation of the process used by this company are described by Smith, Emery & Co., Sept. 14, 1923, in part, as follows:

> The N-T-U Co.'s process employs a cylindrical retort, of 40-tons capacity, having an enclosed grate at the bottom connected with a suction fan, which creates a down-draft within the retort, passing out through the grate, and a set of condenser tubes and scrubbers. The manner of operation is as follows:
>
> The generator is filled with shale crushed to a maximum size of 2 in. A fire is kindled on top of the charge by wood fuel and about 1 gal. of crude oil. The suction fan is turned on, drawing the heat of this combustion down through the charge of shale. In about 3 min. the shale at the top of the charge is burning strongly, and the cover of the generator is then closed so that only enough air is admitted to support slow combustion, which is allowed to continue only on the fixed carbon in the shale.
>
> The volatile matter is carried off at a comparatively low temperature by the hot flue-gases and is caught in passing through the water-cooled condenser and scrubbers. A part of this flue gas is mixed with the air entering the generator and serves to increase the volume of gases passing through the charge without accelerating the combustion. As the distillation proceeds, the fire zone gradually moves down through the charge, driving off the oil some distance in advance. A sudden rise in temperature at the grate indicates completion of the distillation. The blower is stopped and the entire grate is rolled back by a motor-operated screw, allowing the spent shale to drop clear of the generator while hot. The grate is then returned to position and is ready for the succeeding charge. The cycle requires about 24 hr.
>
> It should be noted that the shale itself furnishes the fuel for this process; no external heating is required; the only moving part during distillation is the suction fan which handles the cooled gases from the condenser; the grate and its moving mechanism are not subject to excessive heat nor to wear by abrasion from the shale.

The percentage recovery from this process is reported to be 90 per cent; that is, 36 bbl. to the 40-ton charge. The crude oil obtained has a gravity of about 12 deg. and yields 15 to 16 per cent of gasoline when refined.—Bureau of Mines.

Vol. XXI September, 1927 No. 3

Modern Practices in Automobile-Body Designing

By A. E. NORTHUP[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* DRAWINGS

THE production of beautiful body-designs is not governed by set rules; formulas cannot be expected to show what should and should not be done. Certain generally accepted practices are followed to produce the effects of lowering, lengthening or shortening the apparent dimensions of a car. The employing of cheat-lines for these purposes is described. Certain fundamentals of design, judiciously observed, assist in attaining pleasing lines, as well as comfortable interiors.

Attractive appearance and riding-comfort create desire to buy. Appearance is influenced by many external details. The body must, in effect, be built around the passengers. Head-room, leg-room, seat width, and door width must not be less than definite minima. In a body built for a short-wheelbase chassis, the passengers must sit upright because of lack of ample leg-room, hence more head-room must be allowed than in a long body. To give such a short high body the appearance of greater length, optical illusion must be resorted to by accentuating longitudinal lines and minimizing vertical forms and lines. Cheat-lines are used also to reduce the apparent width of a body. Contrasting colors are resorted to on moldings and reveals to produce some of these illusions. Window shape has an important bearing.

Grace of design and impression of lightness and forward motion depend upon the lines of the fenders, radiator, hood, splashers, running-boards, lamps, and other external parts and equipment. The designing of these, as well as the body, should be delegated to one individual. And his talents and training should be artistic rather than mechanical. Only thus can unity of outline and appearance be secured. The designer should be unhampered by interference from executives who lack artistic ability.

OBVIOUSLY, no stereotyped set of rules can be formulated which will assure the production of a beautiful body-design. The development of pleasing body-outlines and contours is not a mechanical or mathematical problem. Formulas cannot be expected to show what should or should not be done. However, certain generally accepted practices are employed by body designers to accomplish the apparent lowering, lengthening or shortening of a motor-car beyond its actual linear dimensions. By these so-called cheat-lines, body designs that might otherwise be unimpressive are often made very attractive. There are also certain design fundamentals which, if employed judiciously, assist in the attainment of pleasing lines, comfortable interiors and general attractiveness. It is with these fundamentals and design practices that this paper is concerned.

It would seem that the objective to be kept in mind by the automobile body-designer and builder is the creation of a body which will possess maximum sales-appeal. Its appearance and comfort must instill what the salesman calls "the buying urge." Instead of being called upon to defend or explain the shortcomings of the body, the salesman hopes to lead the customer from one appealing feature to another, constantly adding to the prospective owner's enthusiasm until he develops a pressing desire to purchase the car. The motoring public's demands must rule every design decision.

Appearance and comfort are the two major factors that determine the salability of a body. Appearance induces the motorist to inspect the car in the showroom; comfort doubles his desire to own it. Each is of equal importance. A beautiful car that is not comfortable meets strong sales resistance. A comfortable body that is not beautiful does not invite ownership. The body designer must effect a perfect combination of these two major characteristics.

Under the heading of appearance may be grouped many details. First in importance is the outline, or form, of the body. Molding treatment; color scheme; radiator, bonnet and lamp design; interior decoration and trimming material are other important factors. All these features appeal solely to the eye.

Under the heading of comfort can be listed upholstery; shape; head, seat and shoulder-room; leg-room; visibility through windows; ease of entrance and egress; operation of windows and locks; position and completeness of equipment.

FUNDAMENTAL DIMENSIONS THAT AFFECT COMFORT

Because these two important characteristics, appearance and comfort, are so closely allied, it is difficult to consider them individually when discussing body-design procedure. Experience has shown that passenger comfort demands that the body be built around the passengers. Too often the job is started in the reverse order by making an attractive design and then squeezing the passengers into it. Milady may endure discomfort to wear a small stylish shoe, but being squeezed into an automobile body by shoe-horn methods is an entirely different matter. Short, narrow, cramped bodies are rarely good sellers.

Certain minimum dimensions are fundamental and must be adhered to religiously. The more important of these are:

Head-room—Height from cushion to head-lining
Leg-room—Distance from seat-back to pedals or toe-board
Seat width, particularly at shoulder height
Entrance and exit room, door width

Head-room and leg-room are related inseparably. To-

[1] Designer, Murray Corporation of America, Detroit.

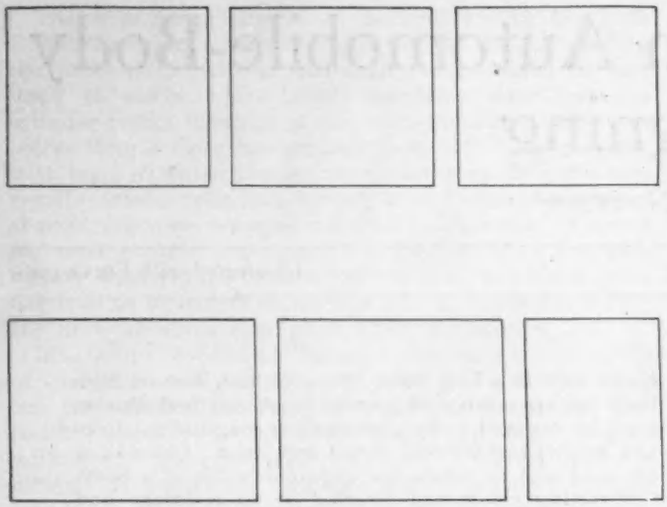


FIG. 1—OLD AND NEW ARRANGEMENT OF SIDE WINDOWS
Formerly the Three Windows Were Nearly Square and of Equal Size, as in the Upper Drawing. Present Practice Is To Make the Forward Two of Greater Length than the Rear Window, as Shown at the Bottom. Although the Area of Both Groups Is the Same, the Lower Arrangement Makes the Group Look Longer and Lower than the Upper Group. By This Optical Illusion a Short-Wheelbase Car Is Made To Appear Longer and Lower

gether they represent the allowance made in the body space for the height of a passenger. This dimension being fixed, over-all height and length of the body are determined largely on how the passenger is seated. This in turn depends on the body space provided on the chassis. If the body space is long, seats may be low and the passengers placed in a reclining position; if the body space is short, the passengers must sit in an upright position, with consequent increased height of the entire body. This controlling factor works to the detriment of body appearance, for the reason that bodies on short chassis must of necessity be made high; and their shortness is thereby exaggerated. The task of the body designer is made more difficult by a short chassis than by a long one. Facing this handicap, the designer must resort to some optical illusion to give the impression that bodies on short chassis are longer and lower than they are in reality. This is accomplished by the use of the cheat-lines mentioned.

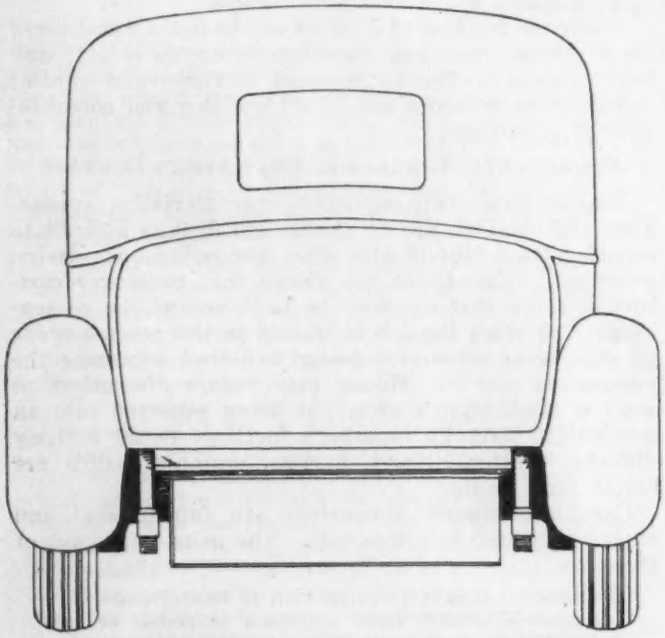


FIG. 2—HOW A CAR IS MADE TO LOOK NARROW FROM THE REAR
By the Use of a Horseshoe Molding in the Back Panel below the Belt, the Wide Expanse of the Back Is Broken Up and Tends To Diminish the Width Due to the Vertical Lines. This Effect Is Further Accentuated by Decreasing the Length of the Rear Window

Similarly, cheat-lines are useful in reducing or increasing the apparent width of the body viewed from the front and rear. If we are to build a comfortable body, the front and rear seats must utilize as much as possible of the width available between the road wheels.

CHEAT-LINES USED TO ACCENTUATE LENGTH

As an example of cheat-line practice, let us take the case of window design. For many years the three side-windows in a sedan body have been proportioned as shown at the top in Fig. 1. All three windows are nearly square and of practically the same size. Now let us arrange these window openings as shown below in Fig. 1. Although the over-all length of the three openings is unchanged, it is evident that this dimension appears to be longer than in the case of the square windows. This example shows the importance of emphasizing in a short body the forms or lines running fore and aft while obliterating so far as possible all vertical effects. In Fig. 3 is shown a body employing this principle. Note the shape of the windows and that the moldings and reveals around the windows are treated in the color scheme to unite all three windows into one long, shallow rectangle. Another feature that exaggerates the length is the rather wide molding along the sill of the body. Painted in a contrasting color it still further accentuates the length of the body. The vertical lines are not marked by moldings, nor is attention called to them in the color scheme. Door openings are of the flush type and are barely noticeable in the completed body. Every effort has been made to conceal vertical lines and forms, while all horizontal notes are accentuated.

Another example of cheat-line practice is the insertion of raised panels running along the top of the bonnet and blending into the cowl. In most cases these panels are painted in contrasting color to carry the eye fore and aft, further adding to the appearance of length. Still another case is that of the so-called horseshoe molding sometimes incorporated in the back panel of the body below the belt, as in Fig. 2. This breaks up the wide expanse of the back panel and tends to emphasize height rather than width, its lines being mostly vertical. Here again the window plays its part in the illusion, being made more nearly square than oblong, inasmuch as we do not wish to accentuate the width of the panel. Figs. 3 and 4 show other design examples which incorporate practices to enhance the appearance of the body.

ARTISTRY NEEDED IN ALL OUTSIDE DESIGN

As indicated in Figs. 3 and 4, length and grace of body-form can be improved greatly by an attractive fender-design. Long sweeping front-fenders give the completed car an appearance of lightness and graceful forward motion that is not presented when abrupt curves are employed.

While on this point emphasis may be placed on the importance of allowing a competent body-designer to assume the entire responsibility for the outline or form of all these exterior units of the chassis that should be in harmony with the body design, including fenders, radiator, bonnet, splashers, running-boards, lamps, and such smaller appurtenances as filler-caps and lamp tie-rods. In no other way can a complete car be designed as a

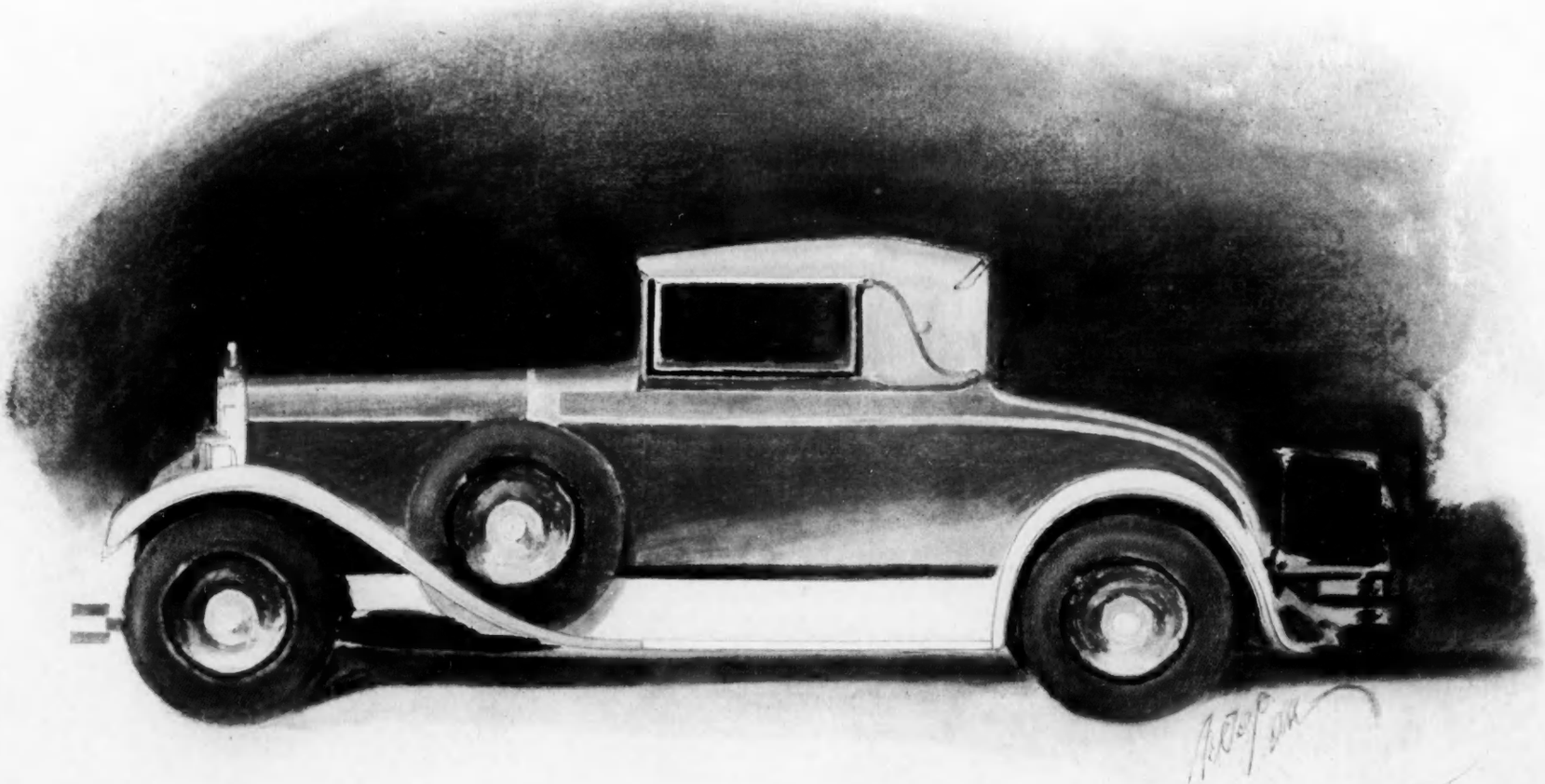


FIG. 3—PASTEL SKETCH OF A CABRIOLET-BODY DESIGN THAT CREATES AN IMPRESSION OF FAST FORWARD MOTION

Long Sweeping Front-Fenders Contribute an Appearance of Lightness and Graceful Speed. Use of a Contrasting Color or Shade on the Deck and Top of the Hood Produces a Long Horizontal Line Where It Meets the Darker Color on the Side, Which Causes the Eye To Travel from Front to Rear and Thus Accentuates the Apparent Length. This Effect Is Enhanced by the Use of a Long Shallow Window in the Top and Also by the Trunk at the Rear

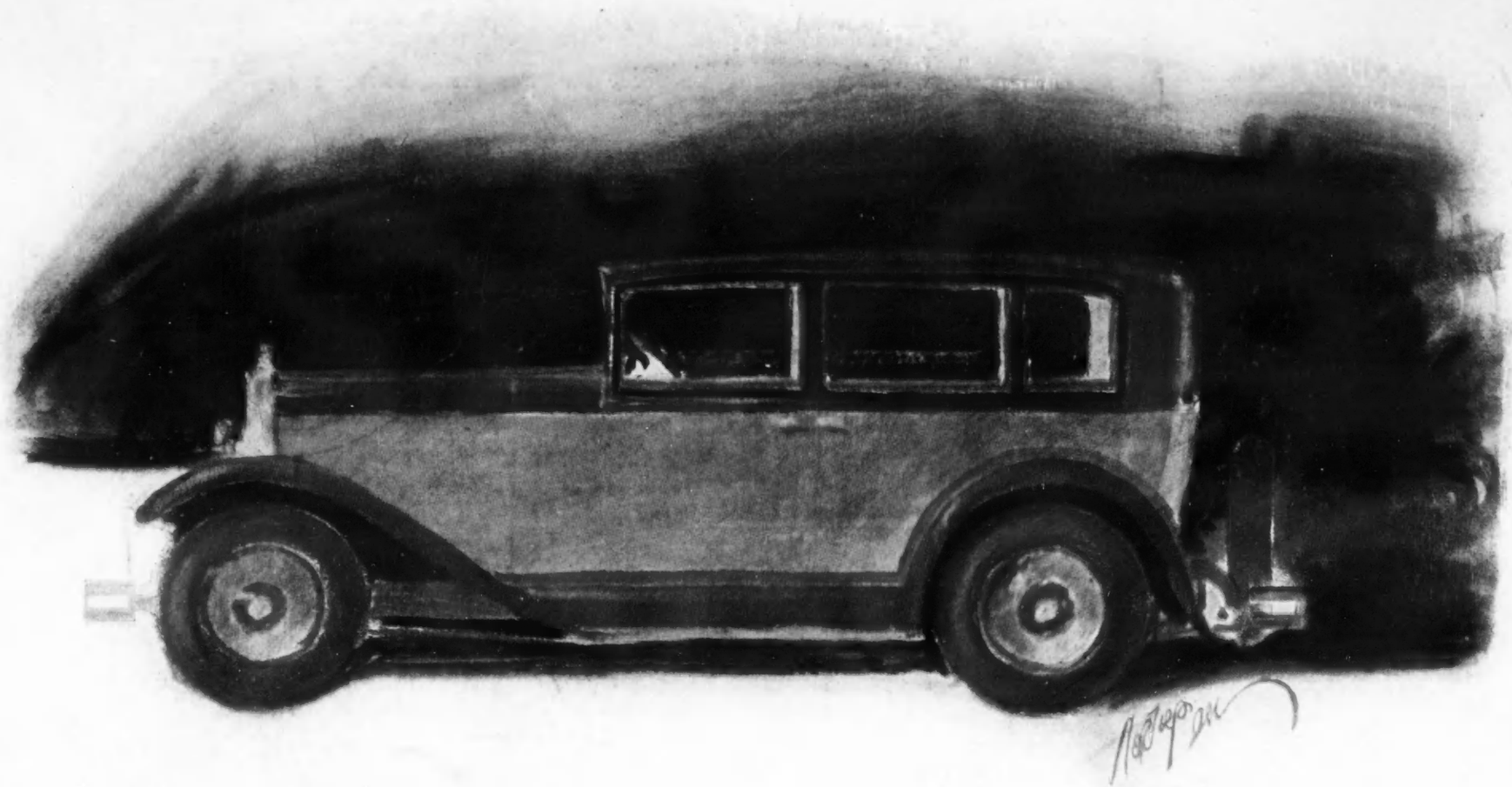


FIG. 4—PASTEL SKETCH OF A SEDAN-BODY DESIGN THAT CONTRIBUTES AN APPEARANCE OF LENGTH AND LOWNESS

All Horizontal and Other Fore-and-Aft Lines Are Accentuated While Vertical Lines Are Obscured as Much as Possible. The Forward Two Windows Are Long and Shallow, and All Three Windows Are Enclosed by a Wide Molding. The Body Top and the Top of the Hood and Cowl Are Finished in a Single Color That Is in Contrast with the Lighter Color of the Side, Which Gives a Sweep of Vision from the Radiator to the Rear Panel. The Front Fender Has a Long Sweeping Form to Produce the Impression of Lightness and Speed. Vertical Door-Lines Are Made Almost Invisible

harmonious unit. Too frequently we see attractive bodies suffering from ugly radiators, cumbersome lamps or crudely designed accessories. These items have often been left to the judgment of men whose training is wholly limited to the design of things mechanical. The resultant design is generally of the T-square-and-compass variety. The entire outer shell of the car should be designed by a single individual whose training and talents are artistic rather than mechanical.

Treatment That Enhances Comfort

Having concentrated on appearance so far in this discussion, let us now see what provisions we have been making for comfort. Having accepted the wide shallow form of door window as advantageous for appearance, we also find it fits certain ideal requirements of comfort. The sight size of the rectangular glass assures adequate vision. The greater width of the doors provides ample entrance and exit openings. Employment of a wide front-door enables the body builder to utilize the same door and pillar stampings for sedans, coupes and cabriolets. So we see that in this case appearance, comfort and economical production are aided by the cheat-line practice.

Color is a most useful tool of the automobile body-designer. He should keep color treatment constantly in mind when laying out his designs. With proper utilization of contrasting colors he can accentuate this or that feature of a body in such a manner as to make the completed car most striking in appearance.

So far as the interior of the body is concerned, it is my opinion that appearance and comfort are again closely intertwined. Ornate cloth-patterns, heavily figured laces running hither and thither, or a preponderance of buttons, plaits and tassels, destroy the restfulness of the interior. Simple tailored design, on the contrary, tends to encourage relaxation and restfulness. Wide coach-laces and other decorative materials are relics of the carriage days. Carriages were seldom used for long journeys, but our present-day motor-cars carry their occupants on long overland trips. It seems best to have the design of the trimming and interior fittings of the body pointed toward simplicity and richness.

The Body Designer Must Be a Creator

Style in body lines should change logically from year to year. As in other fields of commercial artistry, we must be ready with new ideas when our customers tire of the characteristics of appearance which have become conventional through too general usage. To predict what will or will not be the vogue is rather hazardous. It is the body designer's responsibility constantly to seek novelties of design which will intrigue the motoring public. To be of the greatest value to a body-building organization he must be a creator, not a copyist. Our industry is too much given to following the leader. How frequently we encounter the automobile executive who bases his body-design specifications on instructions to make this or that just like the new Tenstrike Eight. Adherence to such practice will keep that manufacturer at the rear of the parade. He must create new features if he hopes to lead.

Custom-Body Designer Rules His Realm

In closing, let me register a plea in the interest of the body designer. Much of the lack of unity and beauty in automobile design of the past can be attributed to the unfortunate interference in body-designing activities by executives not qualified by experience, training or talents to dictate the form a given body should take. They do not realize that there is a wide gap between the possession of good taste and real artistic ability. The two are easily confused. How frequently we hear executives comment with favorable enthusiasm on this or that design at the Automobile Salon. They express criticism of their own designers at the factory because they do not seem competent to produce equally attractive designs. Most of them, if not all, fail to realize that the custom-body designer is king of his realm. From the laying-down of the small-scale sketch to the completion of the sample body, his word is law; and it is no wonder that his bodies possess a unity of outline and appearance. Every detail reflects his personal judgment; to each he applies artistic taste unhampered by the criticisms and suggestions of others unqualified to collaborate with him. The result can never be a patchwork quilt of unrelated ideas. Experience seems to demonstrate that the most attractive motor-car bodies are the product of experienced designers working without interference from well-meaning executives who hope to assist with their criticisms. Greater accomplishment seems to be promised by placing the entire responsibility for appearance on men whose training, talents and temperament are along artistic lines.

THE FOREMAN

A MINOR executive is responsible for getting jobs done. He is the person to whom the worker is immediately responsible. To the working force he represents the management of the company. He is not responsible for doing production or service jobs himself but is responsible for having the working force do them under his supervision and direction. There is no one lower in authority to whom he can pass on this responsibility. To a considerable extent he is left to work out his own ways and means.

It is generally characteristic of the minor executive's job that he has authority in his department commensurate with his responsibilities. In an organization that has not been functionalized, the foreman has a many-sided job. He is responsible for getting out a product according to specifications in the shortest possible time and at the lowest possible cost; he may also be responsible for hiring men, laying off men from his department, planning his work, ordering his equipment and supplies, and looking after the interests of his men. In such an "old-fashioned" organization, where there are no functional minor executives, the foreman has the maximum of responsibility; hence, it naturally follows that he has the maximum of authority within his department. Just as soon as an organization of this type is functionalized by adding agencies such as an employment department, purchasing department, planning department, and shipping department, the foreman is gradually relieved of a part of his responsibilities. Naturally, his authority over the work which he supervises is more circumscribed, and this is increasingly true as more and more headway is made toward a highly functionalized organization.—Frank Cushman in Foremanship and Supervision.

Rubber as a Material for Mechanical Engineering

By W. A. GIBBONS[1]

INDIANA SECTION PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

Rubber is waterproof, is a good insulator, is very resistant to the weather and to chemicals and can be molded and otherwise fabricated readily. Many of these properties have been utilized, often unconsciously, by engineers who were employing rubber chiefly on account of some other characteristic; but none of them would be particularly useful if rubber did not, in addition, possess unique mechanical properties such as those which permit hose and insulated wires to be bent, tires to be flexed repeatedly and inner tubes to be inflated. Some of the fundamental mechanical and elastic properties of rubber are discussed briefly in comparison with those of steel in the hope that, having a better understanding of them, engineers will increasingly consider rubber as a desirable material that is suitable for constructional purposes because of these primary mechanical properties.

RUBBER is unlike any other engineering material in several respects. First, its properties can be made to vary over a much wider range than can those of any other known material. Compounds can be made which have qualities varying from the tough horny consistency of hard rubber to a soft more or less yielding product. But it is the intermediate type of rubber familiar to all in the form of tires, inner tubes, elastic bands, and the like which interests us at present. Even in this group rubber has a wide range of properties, and it is particularly to these properties and their utilization that attention is called.

To the engineer, one of the most remarkable characteristics of rubber is its ability to permit an enormous change of shape when a load is applied and to resume its original shape when the stress is removed. A piece of well-vulcanized high-grade rubber-compound can be stretched to 10 or 11 times its length without rupture or appreciable permanent deformation. Another property, in some respects fully as remarkable, is the high tensile-strength possessed by rubber. A piece of rubber like that just referred to may have a tensile-strength, calculated on the original cross-section, of 5000 lb. per sq. in. The actual strength of such a sample at its breaking point is, however, about 50,000 lb. per sq. in., calculated on its cross-section at the time of breaking; hence, its tensile-strength approaches that of steel.

From these two considerations of stretch and strength, we pass to the third interesting property; namely, the ability of rubber to absorb energy. While many materials surpass rubber in strength, none approaches it as a medium for the absorption of energy. The stress-strain curve of rubber is not a straight line, but for the time being it is assumed to be straight. Fig. 1 shows a steel spring and a rubber band that have approximately the same elastic properties when not loaded. In Fig. 2, the spring and the rubber band have the same elastic properties when loaded.

Let us consider a piece of rubber having a cross-section of 1 sq. in. and a working length of 1 in. Such a piece of rubber can be stretched to a total length of 11 in. If the load at this elongation is say 4000 lb. and we assume a straight-line stress-strain curve, the rubber will have absorbed 1600 ft-lb. of energy. Such a piece of rubber will weigh about 0.04 lb.; hence, 1 lb. of rubber similarly treated will absorb 40,000 ft-lb. of energy. If such an elongation occurs in cycles of 1 min., this 1-lb. piece of rubber which occupies about 25 cu. in. of space is absorbing energy equivalent to the output of a 1¼-hp. motor. A steel spring capable of absorbing the same amount of energy would weigh 50 to 100 lb., depending upon the type of steel used. Rubber would not ordinarily be used with such a small factor of safety; however, as a result of having such great ability to suffer distortion and to absorb energy, smaller distortions and loads can be applied and removed repeatedly without deteriorating the material appreciably. The rubber tire probably is the best example of repeated application and removal of load, but the properties of distortion and energy absorption are utilized in practically all rubber articles such as engine mountings, spring shackles, radiator hose, molded parts and strips, and many others.

Let us now consider what happens to the mechanical energy which rubber can be made to absorb. If a piece of steel in the form of a spring is stretched and the strain is plotted against the stress, a straight line is obtained which is the graphic representation of Hooke's law. The area under this curve, in proper units, represents the number of foot-pounds of energy absorbed. If the spring is released and the elongations and loads are noted, the first curve is retraced and, since the areas are equal, we say that the energy absorbed is zero and that such a piece of steel is perfectly resilient. If, however, we study in detail the stress-strain curve of rubber, we find a different state of affairs. First, the curve is not a straight line. It has three main sections. The first section is one which might be called that of initial stiffness, when a large increase of load is required to extend the specimen. The second section is a practically straight portion where, if we knew nothing of the previous or future life of the specimen, we would say that

[1] M.S.A.E.—In charge of research department, general laboratories, United States Rubber Co., New York City.

it is obeying Hooke's law. Just about the time one would expect to reach an elastic limit and to find on further stretching a greater elongation per increment of load, the sample suddenly stiffens and shows less extensibility per increment of load. This is one of the most remarkable properties of rubber, and I know of no other material which acts in this way.

If the load is now removed gradually and the elongations are noted, we find that the curve for retraction is not identical with that of extension, but that the loads at the same stretch are lower. The difference in the areas under the curves, that is, the area of loop between them, is the hysteresis loss and is irreversible energy. It is this property of practically perfect restitution of form, with imperfect restitution of energy, which makes rubber valuable as a shock-absorbing material. Here again we find a property possessed by no other known material to the same degree. This can be demonstrated easily by applying the same elongations to a rubber band and to a steel spring of about the same characteristics, and then releasing both; the steel spring continues oscillating for a long time, while the rubber band quickly comes to rest.

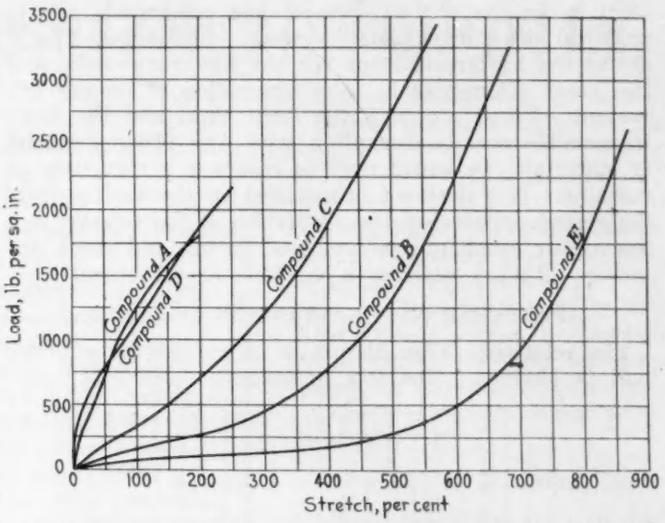


FIG. 3—STRESS-STRAIN CURVES OF FIVE DIFFERENT COMPOUNDS OF RUBBER

These Compounds Vary from a Pure-Gum Stock to Two That Are Highly Compounded. It Is Evident That the Compounds Differ Greatly in Stiffness

EFFECT OF COMPOUNDS

The resiliency of many materials can be modified by special treatment, such as tempering, but the useful range is limited. Rubber, however, can be modified greatly by the vulcanizing process and by the admixture of other materials. For example, considering five different compounds of rubber, *A*, *B*, *C*, *D*, and *E*, varying from a pure-gum stock to two that are highly compounded, Fig. 3 shows their stress-strain curves. It is evident that the compounds differ enormously in stiffness. If we consider the load necessary to double the length as an index, it runs from 30 lb. in the softest stock to

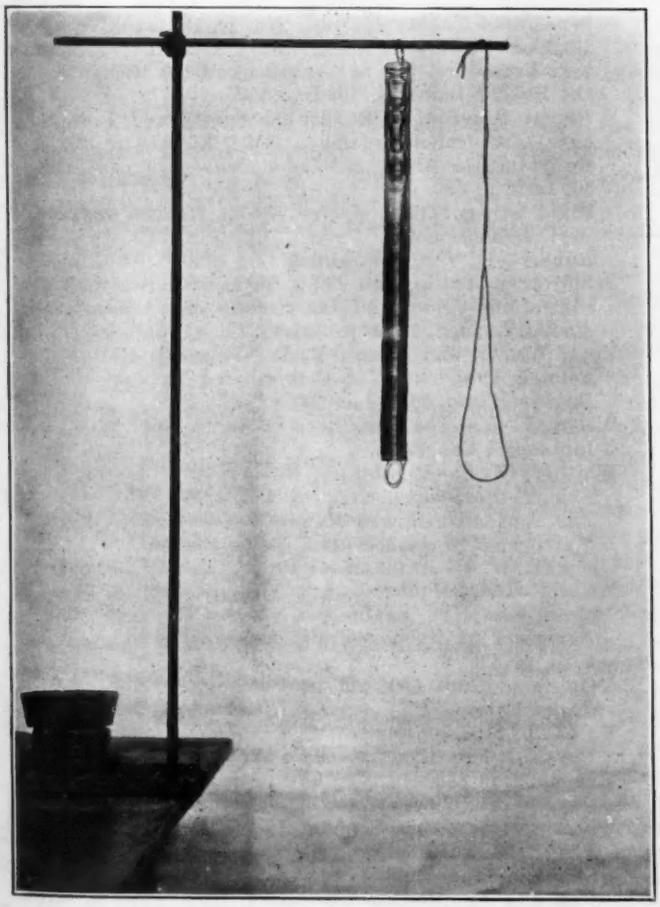


FIG. 1—ELASTIC PROPERTIES OF STEEL AND RUBBER COMPARED

The Steel Spring and the Rubber Band Shown Have Approximately the Same Elastic Properties When Not Loaded

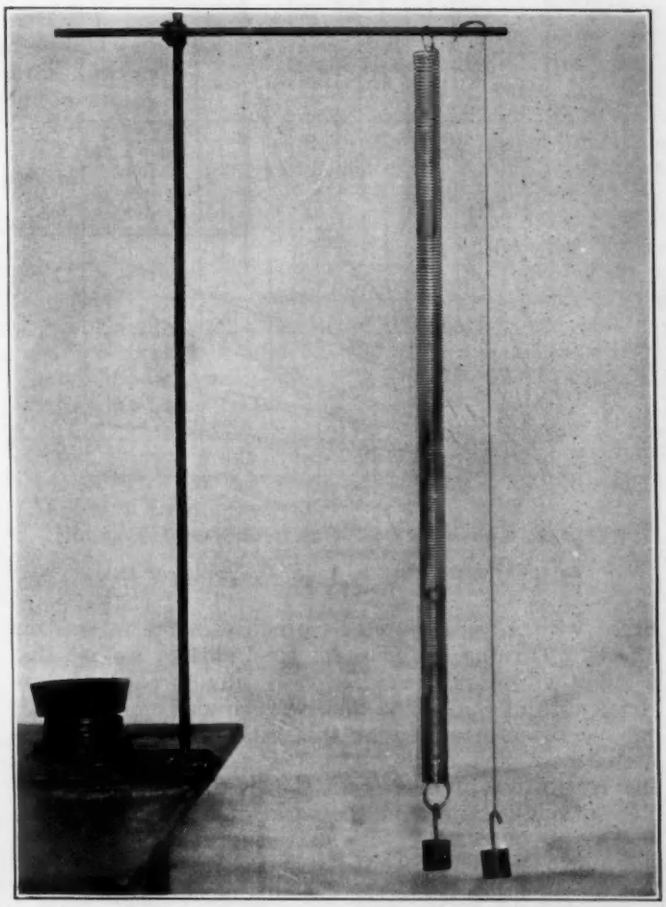


FIG. 2—ELASTIC PROPERTIES OF STEEL AND RUBBER COMPARED

The Steel Spring and the Rubber Band Shown Have Approximately the Same Elastic Properties When Loaded

1200 lb. in the stiffest, yet all five compounds are in practical use for various purposes. Likewise, Fig. 4 shows the hysteresis loops for the five compounds, and the great differences in total absorption of energy are evident. To secure both the same total and the same irreversible energy-absorption with any other material or materials, we would need to resort to a structure or machine. If a dash-pot is installed on the steel spring, the spring approaches the properties of the rubber; but the rubber constitutes a combined spring and shock absorber. Rubber replaces a machine or structure.

Application of the Properties of Rubber

The relatively large distortion of rubber for a given load is obvious. The low modulus of elasticity com-

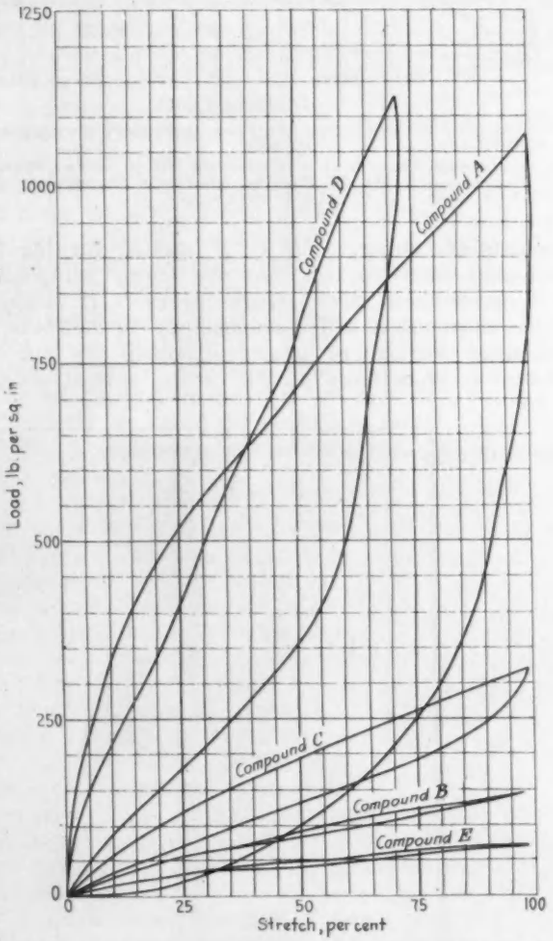


Fig. 4—Hysteresis Curves of Rubber Compounds of Different Degrees of Stiffness
The Great Differences in Total Absorption of Energy Are Evident

bined with a high hysteresis produces some interesting effects. Turning again to the steel spring, we see that a slight vibration is carried faithfully through the entire length of the spring and, with proper mountings, it can be demonstrated that this vibration might be reflected back and forth for a long period, so perfect is the restitution of energy in the case of steel. If the steel is not arranged in the form of a spring, a small shock will be carried with extreme rapidity, owing to the high modulus of elasticity of the metal. With rubber, on the other hand, the modulus of elasticity is low; small shocks produce vibrations of lower frequency and the high hysteresis makes them readily absorbed. The same piece of rubber can function simultaneously in two ways; it can absorb large displacements and at the same time obliterates most if not all small vibrations.

In an automobile, rubber can be used to absorb shocks and particularly to absorb the vibrations between the springs and the chassis, between the engine and the chassis, and between the propeller-shaft and the chassis. It can be used in a supplementary way to give a vibrationless connection between the body and the chassis, between the chassis and parts of the equipment such as the gasoline tank, the steering mechanism and the like. Rubber is particularly valuable in these locations, since it breaks up vibrations and prevents them from being carried from one metal part to another. By separating with rubber, from the other parts of a car, those members in which its vibrations may originate, the vibrations are localized and thus the trouble is eliminated at the source. Let us hope that rubber shortly will take its place among the recognized structural materials so that engineers can find data in engineering handbooks on its mechanical properties.

No attempt has been made to discuss the principles of rubber compounds and the effect of compounding. Much work has been done in this important field, and a list of references on the testing, the physical properties and the compounding of rubber is appended.

Bibliography

Evans, W. W.—Abrasive Testing of Rubber Goods—*India Rubber World*, May 1, 1924, p. 506.

Hatschek, Emil—The Stress-Elongation Curve of Vulcanized India-Rubber—*Journal of the Society of Chemical Industry*, London, Nov. 15, 1921, p. 251-T.

Schidrowitz, Philip—Corrected Strain-Curves for Rubber—*India Rubber Journal*, Oct. 29, 1921, p. 679.

Physical Testing of Rubber and Its Relation to Factory Procedure—Third Year-Book of the Institute of the Rubber Industry, 1924, p. 319.

Recent Progress in Rubber Chemistry and Technology—*Chemical Age*, London, April 2, 1921, p. 390.

Resistance to Abrasion—*India Rubber Journal*, Oct. 30, 1920, p. 889.

Rigid Stress-Strain Curves—*India Rubber Journal*, Sept. 4, 1920, p. 453.

Rubber—D. Van Nostrand & Co., 1920.

Schidrowitz, Philip, and Bean, P. L.—Studies in Vulcanization—*Journal of the Society of Chemical Industry*, London, 1922, p. 324-T.

Vogt, W. W., and Evans, R. D.—Poisson's Ratio and Related Properties for Compounded Rubber—*India Rubber World*, May 1, 1923, p. 497.

Weber, L. E.—The Chemistry of India Rubber—J. B. Lippincott Co., 1926.

Whitby, G. S.—Plantation Rubber and Testing of Rubber—Longmans, Green & Co., 1920.

The Tensile Testing of Rubber—*India Rubber World*, March 1, 1923, p. 362.

Wiegand, W. B.—Mechanical Properties of Calendered Sheet—*India Rubber Journal*, Nov. 5, 1921, p. 733.

More Complete Evaluation of the Pigment Reinforcement of Rubber—*India Rubber World*, May 1, 1925, p. 475.

Optimum Cure Criteria in Vulcanized Rubber—*Industrial and Engineering Chemistry*, November, 1926, p. 1157.

Physical Test Graphs—*India Rubber Journal*, Nov. 25, 1922, p. 889.

Physics of Rubber—*Journal of Industrial and Engineering Chemistry*, September, 1922, p. 854.

The Resilient Energy Criterion as Applied to the Shape of the Rubber Stress-Strain Curve—*Industrial and Engineering Chemistry*, June, 1925, p. 623.

Rubber Energy: Some Aspects of the Rubber Stress-Strain Curve—*Journal of Industrial and Engineering Chemistry*, February, 1921, p. 118.

The Relation of Research to Industry

By W. S. JAMES[1]

SEMI-ANNUAL MEETING PAPER

DURING somewhat more than 15 years' contact with both "pure" and "commercial" research work, I have observed a general belief that research is something mysterious and uncanny. This belief has been fostered rather than corrected by the popular-magazine and newspaper versions of scientific research. At present I feel that the word "research" is losing its true meaning, and research endeavor, valuable as it is, may suffer from this misunderstanding.

To the many definitions of research that have been given I will not add; but I will endeavor to illustrate by example what it means to me.

In 1785, after the major constituents of air were determined to be oxygen and nitrogen, Henry Cavendish asked himself: "Can there be any other substances in air?" He confined a quantity of air in a vessel, passed electric sparks through it until all the oxygen present had been combined with some of the nitrogen and absorbed the nitrogen oxides thus formed. He then passed fresh oxygen into the vessel and continued the sparking. After long and repeated trials he absorbed all of the air except a small bubble which would not oxidize, and estimated that this bubble was not more than 1 per cent of the original volume. He therefore concluded that if any gases other than oxygen and nitrogen were present they amounted to not more than 1 per cent.

More than 100 years later, in 1894, Lord Rayleigh and Sir William Ramsay were determining the densities of hydrogen, oxygen and nitrogen with greater accuracy than these densities had previously been known. During this work they noticed that the density of nitrogen obtained directly from air and that obtained partly from air and partly from ammonia differed by as much as 0.5 per cent, although their means of measurement were much more accurate than this. Why could they not obtain the degree of accuracy desired? They repeated Cavendish's experiment, and when only the small bubble of gas remained they investigated its properties with the spectroscope, which was not so fully understood in Cavendish's time. The bands shown by the spectroscope were those of no previously known substance. Thus argon was discovered and the discrepancy in the density of nitrogen was eliminated.

[1] M.S.A.E.—Research engineer and head of research department, Studebaker Corporation of America, South Bend, Ind.

Research is not something mystical; even what is called pure research is not essentially different from the application of knowledge and common sense to the experimental solution of the everyday problems of the ordinary man.

A good research man should not be satisfied to leave any question unanswered. He should have at his finger tips the fundamentals of physics and chemistry, and he should be a man of broad information in the various industries and sciences, because the fundamentals of all are interrelated.

A plan should be put into effect whereby college laboratories and similar institutions can work in cooperation with industry, to the benefit of both the student and industry.

Most of our industrial research has been confined to production. There is a growing need of research in the sales and other departments so they will not be outstripped by production.

Thus Henry Cavendish satisfied, to some extent, his curiosity as to the composition of air; and thus Lord Rayleigh and Sir William Ramsay solved the problem as to what made their measurements of nitrogen disagree, the discovery of argon being a by-product.

THIS, TOO, IS RESEARCH

In 1927, Abie O'Brien had never had a car and wondered how it would feel to own one. He saw a car with a four-cylinder engine and a planetary transmission for sale for $50 at a Detroit open-air salesroom. Feeling reckless, he put on a long face and, after a heart-rending discussion with the salesman, paid $25 and chattered down the street. Within about two blocks the engine coughed once or twice and stopped. Abie could not make it start again. His friend, Patrick Cohen, came by, saw Abie, and admired the car so much that Abie asked him if he wished to buy it for $25. Patrick paid the cash and cranked the engine. To Abie's dismay it started; but it stopped before the car left the curb. Patrick sat with dismay in his heart for a few seconds. Then he had a "hunch." He lifted the seat, looked into the gasoline tank and smiled. Going to a gasoline station, he bought some gasoline, put it into the tank, cranked the engine, and started off.

Thus Abie satisfied some of his curiosity as to how it felt to own a car; and thus Patrick solved the question of why the car stopped, learning something about Abie as a by-product.

Henry Cavendish, Lord Rayleigh and Sir William Ramsay had solved problems in pure research, so called. Abie O'Brien and Patrick Cohen had done the same; but they did not know it by that name. On examination the steps followed by these men will be found to be identical. They were either curious or confronted with a definite problem. Their curiosity was more or less satisfied by *actual trial*, not by aimless discussion. Their problems were solved by guessing with greater or less accuracy at the probable answer and checking the guess or hypothesis by experiment. All used the information and facilities at their disposal to satisfy their curiosity and to solve their problems, although their information and facilities were vastly different in character. The basic actions were identical, although the causes and reactions may have been different in source and intensity. Anyone will recognize many examples

in his everyday life that are exactly similar to the ones given. You may have been faced with a problem to the solution of which you were not able to bring all available information. Someone else may have been able to solve your problem very quickly merely because he had at his disposal correct information upon which to formulate a plan of action or hypothesis, as well as the facilities for checking his hypothesis.

Neither Mysterious nor Idle

When research is viewed from this angle it is certainly not mysterious. Neither is it *idle* curiosity. It should be easy to see why anyone working in research should have a well developed, natural and honest curiosity, should be able to tap unusual sources of information and should be able to perform experiments to check suggested solutions. Problems which require immediate solution are common in any industry today. The quickest solutions of such problems are obtained when they are attacked by someone with an honest, inquiring mind who has access to all available information. When essential information is lacking it is impossible to check experimentally with ideal accuracy, but a more nearly correct answer can be obtained with common sense and attention to facts previously established.

In the automotive industry it is often said that not enough time is available for the solution of any but immediate problems. It also seems that very few men in the industry are considering seriously what problems will confront them 1 year or 5 years ahead. At our present stage of industrial development very few facilities have been coordinated with industrial activity for carrying out work of this nature. University laboratories and similar institutions are the most promising sources for the solution of such problems, but their contact with industry is usually limited and their knowledge of future problems of industry is, therefore, lamentably weak. Were it possible to work out a scheme of cooperation between industry and such institutions, to work out problems of general or potential industrial interest, a two-fold benefit would result, as industry would be provided with information at an opportune time and the men leaving the universities would have a clearer understanding of the problems of industry through the closer contact of their professors with industrial problems.

Coordination of Education and Industry

The mechanism of such a scheme could not be worked out in a day. Many problems would be involved. Some of them, such as patent rights, can be foreseen; others that cannot be foreseen would appear after cooperative work was begun. There has been much conversation on this point, and instead of more conversation I would like to recommend a little action.

One of the possible by-products of such a relationship between the universities and industry would be the retention in this particular line of endeavor of the men who are best fitted for it. It has often been said that a university trains men. I believe this is not a correct statement; no university can train a man. Rather, the university is a place where men can be selected, where each man can be afforded an opportunity to became familiar with a number of lines of endeavor and to select from among them the one for which he is best fitted. Present university courses seem to force a man to continue one kind of endeavor that has been previously selected without sufficient knowledge, rather than to provide him an opportunity to learn for what work he is best suited. Some men show marked aptitude for research work. Such of these men as are outstanding should be so fitted into our economic structure as to utilize their abilities to the maximum. If they could work with commercial objectives in the university atmosphere, much good would result.

THE DISCUSSION

B. J. Lemon[2]:—Eternal research is the price that must be paid if American industry is to survive. The industry that will last is the industry whose advisers of finance, advertising, purchasing, manufacture, sales and service know what is going on in all phases of their particular industry, and whose executives comprehend when and how to apply information made available through research.

In the application of science to American industry, research generally has been confined in the past to manufacturing methods. Our recent progress is due chiefly to such application, and we have every reason to hope that through the establishment of an ever growing number of technical laboratories this success will continue.

But production is only one phase of a successful business. What will it profit us to double our production if marketing does not keep pace? What will it profit us to make the best automobile in the world if our finance, advertising, sales, and service units are not in step with our production schedule? Studying the chemistry and physics that underlie economic production while neglecting other important phases of a business serves only to emphasize the unbalance that throws a violent shimmy into the whole machine. Power-wasting boilers and machinery, antiquated corporation-finance, advertising lacking in appeal, old-fashioned sales-methods, and neglect of the product when sold have little to do with chemistry and physics, yet they are all sectors of the industrial wheel and must receive balanced consideration.

Unquestionably many of us stand convicted of failing to apply the research or fact-finding viewpoint to all our industrial problems. When a depression comes we are inclined to think we can recover either by engaging a few high-priced chemists, advertisers or salesmen to work out the secret of recovery, or by effecting economies through reduction of personnel in what seem to be our non-paying departments, generally including in that category scientific and commercial research. Progress is not made by either expedient. Building up a workable fund of knowledge is a slow process. Research requiring several years cannot be extemporized in short order.

In automotive fields we are developing high-precision instruments; we are establishing proving-grounds to find out the weak points of our own and the strong points of competitors' cars; we are developing fuels for high-compression engines; we are making durable and easily-applicable paints and lacquers that are cheap; and we are producing uniform rubber by preserving and mixing rubber milk in large quantities. We seem to be able to do anything we wish along such lines because we have built up a fund of knowledge based on the sciences of physics and chemistry applied to production.

Contrast these advances with the present lack of knowledge of the actual rate of depreciation of used cars and the specific causes that influence this rate; with the uncertainty as to whether a series of expensive advertisements will or will not draw; with the woeful lack of in-

[2] M.S.A.E.—Field engineer, United States Rubber Co., Detroit.

formation and of psychology in our wholesale and retail sales methods; and with the absence of tact and diplomacy in our service contacts. The contrast pictures the value in the one case of fact-finding research, and in the other of hit-or-miss methods.

We need in American industry more fact-finding in departments other than production, more sympathy with and understanding of fact-finding departments among executives, more advertising research, more sales research and more service research. The only kind of research that is dangerous is research that is neglected.

Increased Sales Possibilities

David Beecroft[3]:—At times we ask: "Will we really sell 4,000,000 cars this year?" Whenever that doubt arises I think of conditions on my boyhood farm. My home was 9 miles from town and 2 miles from church, school, post office, blacksmith shop, and sawmill. We used to have for personal transportation two blooded road-horses worth $135 or $140 each, a three-seated democrat wagon, a single buggy, and double and single harness. All together we had about $600 invested on that farm for road transportation, as these horses were never used for any farm work. On that farm today there are two automobiles, which, considering the relative value of the dollar, represent a smaller investment for personal transportation than we had on the same farm 40 years ago.

It is said that every farmer should have an automobile, but I believe that every farmer in this Country needs two automobiles. If you have lived on a farm and know the Saturday and Sunday program of father, mother and the boys, you can realize the greater possibilities of our industry here.

Production in the automobile and other industries from 1900 to 1915 was on a rising curve. As we had plenty of immigration, the population of the Country was rising also, so there was no problem of distribution or sales. Wholesalers and retailers needed no high-pressure salesmanship. After 1915 a fundamentally new set of conditions came in. There was an amazing increase in production and at the same time immigration was shut off. For the first time the curve of population lagged behind the curve of production. The problem of industry changed from one of production to one of distribution or selling. Today the neck of the bottle in our industry is selling. Manufacturing has been made easy; selling is the serious problem, and few of our large companies have the correct perspective of the consumption field of the Country.

Forty-eight per cent of the cars are today owned in and around towns having a population of 5000 or less These vehicles are serviced in the same small towns and the limitations of these towns should be considered in designing cars and in planning repair equipment. The people in these small towns are buying more and more cars and the companies that increased their sales so enormously during the last 3 years have made their increases through sales in such towns. We are just beginning to cultivate this field. When I think of all this, I believe we may sell 6,000,000 instead of 4,000,000 cars per year.

Chairman R. E. Wilson[4]:—Mr. Lemon and Mr. Beecroft touched upon a very important point to which we must give more attention, the need for more research in selling and advertising. In the oil and other industries, are many departments in which research and development work and better engineering have cut costs in half; yet a large share of that saving seems to be swallowed up immediately in advertising and selling costs, which trend upward in spite of earnest attempts to keep them down. Part of the reason for that trend may be the very lack of research in selling methods that has been mentioned, and that in turn may be due to the segregation of research men. The typical research man is a man of inquiring mind, a man who is intelligently curious about whatever he runs across, a man who preferably works along with certain theories in mind as to what is happening behind the scenes; and when something at variance with one of his theories appears he cannot rest until he finds out what is wrong with either the theory or the experiment. Such men are generally placed and kept in research and development work. On the other hand, those in charge of research work frequently say with regard to some bright young man with a pleasing personality who cannot tie himself down to a problem: "Well, he is not the research type; we would better put him in the sales department." In my opinion, if we placed a few good research men in the selling organizaton and a few good salesmen in the research organization both would be better off.

H. L. Horning[5]:—I will explain in terms of research why the Milwaukee Section failed to win the chassis-assembling contest at the Summer Meeting. Two fundamentals were involved that occur in every research problem.

The first thing we did was to obtain water for the radiator, and we hid it so the other contestants would not take it away from us, then could not find it when we were ready to go. That is what is done with much research work. Good information is obtained, concealed from others and then forgotten. This may be applied to the great progress in regard to detonation. At the General Session of the meeting we were told that an atom can be ionized by being bombarded by an electron or by radiation. This has been known for a long while, yet in our research on detonation this fact is almost forgotten. We spend millions every year forgetting this fact.

Closely related to this error is another, that of failing to catalog information so that it is easily available.

A second reason for failing to win the contest mentioned was that we lost 3 min. because someone forgot to turn on the gasoline. This illustrates how we sometimes go over and over the same thing until we become heedless and then omit some important step. The gasoline feed of an engine that was sent by an outside company to our laboratory would not work. The reason was found to be that the mixture changed with the level of gasoline in the tank. At one level the mixture was impossibly rich, and it ranged from that to a mixture which was so lean that the engine would not run. A trouble that seemed to be very complicated turned out to be an elementary problem in hydraulics. The significant fact is that the research man who attacked the problem was able to recognize it as such and find an easy remedy by the application of a simple principle.

A research man should be well read in all the sciences. Industries or fields of research other than his own may give him the nucleus of the solution of his problem, as all industries and sciences are related in their fundamentals.

[3] M.S.A.E.—Vice-president, Chilton-Class Journal Co., New York City.

[4] M.S.A.E.—Member of research council, Standard Oil Co. of Indiana, Whiting, Ind.

[5] M.S.A.E.—President and general manager, Waukesha Motor Co., Waukesha, Wis.

The Electric Drive as a Motorcoach Transmission

By CHARLES FROESCH[1]

NEW ENGLAND SECTION PAPER *Illustrated with* PHOTOGRAPHS AND CHARTS

THE engineering factors involved in the adaptation of the electric drive as applied to the motorcoach are presented by the author, who also enumerates the limitations of design. To raise the power curve at the higher engine-speeds and within the most efficient speed-range of the engine, which corresponds generally with a piston-speed of from 1200 to 1600 ft. per min., without unduly sacrificing engine torque at the lower speed, the valve-timing must be changed. The author illustrates what effect this has by presenting data obtained with a four-cylinder engine of 4¼-in. bore and 5-in. stroke, together with other tabulated data and charts.

With regard to the advantages and disadvantages of the electric drive, it has been fairly well established that the greatest asset, as applied to the motorcoach, is the permissible increase in scheduled speed where traffic is congested. Other advantages are its quietness of operation due to the elimination of the selective-gearshift transmission and also to the ease of operation, because the driver has but two operations to perform in addition to steering. The last advantage has a tendency to increase safety, renders fare collecting easy, saves time, and lessens the physical fatigue and the mental strain on the driver of the motorcoach.

Some of the disadvantages of the electric drive are its high initial cost and its greater weight, the latter being from 1250 to 1650 lb. more than that for a vehicle equipped with the conventional clutch and gearbox. The greater weight requires that more pounds must be carried as dead-weight. It is stated that the electric drive is comparatively inefficient for vehicles having low power-weight ratio. There is a slight time-lag at the start of acceleration which is caused by the necessity of building up the necessary magnetism and potential in the generator, but it does not become serious until traffic conditions call for 15 or more stops per mile. It is stated also that the fuel consumption is greater with the electric drive and that, in the future, this drive must stand or fall on its economic merit.

THE constantly increasing popularity of electricity for all sorts of applications which require some form of flexible motive-power is, I believe, one of several factors directly responsible for the comparatively recent revival of the electric drive as a motorcoach transmission. In the last few years the street-railway companies have recognized the economic advantages of the motorcoach in city transportation either as a feeder or as a supplement to existing forms of transport, and therefore they have sought to use a vehicle having a transmission automatic in its action and one that would conform in operation with their street-cars in view of simplifying operating and servicing problems. Furthermore, the prevailing high traffic-density in large cities, which directly affects the number of stops to be made per mile, requires an extremely flexible transmission, irrespective of efficiency to a certain extent. For this kind of work the electric drive is admirably suited.

The development of larger vehicles combined with the variable passenger-loads that must be handled in city-service work, together with low cost of operation, means a low horsepower-weight ratio which necessitates the use of the conventional gearbox for a greater part of the running time under maximum loads. The electric drive has been adapted to fit the characteristics of the motorcoach engine to obviate this and therefore obtain a higher rate of acceleration from a standstill, under these conditions, by eliminating gearshifting.

ENGINEERING FACTORS AND DESIGN LIMITATIONS

Before describing recent developments embodying the electrical transmission of power, some of the engineering factors involved in its adaptation and limitations of design will now be discussed. The electric drive as applied at present to the motorcoach consists essentially of a direct-current generator driven by the engine, either one or two series-motors driving the rear axle by one or two propeller-shafts, and a hand-operated controller which acts as a switch. The engine-generator group can be compared to that of a power station but having variable speed and, therefore, variable voltage.

With the electric drive, the nature of the engine-torque curve and the rate at which it reaches a peak are not such important characteristics as is brake-horsepower, because best performance depends upon the number of kilowatts that can be generated in a given time, especially during the acceleration period. After this period it is highly desirable that the windings of both units be balanced to operate within the most efficient speed-range of the engine, corresponding generally to a piston-speed of from 1200 to 1600 ft. per min. I mention this speed in terms of feet per minute of the pistons rather than revolutions per minute of the engine because it gives a more exact indication of what has been found to be the most efficient and reliable speed for heavy-duty motorcoach engines as now made.

To raise the power curve at the higher engine-speeds and within the previously mentioned range without unduly sacrificing torque at the lower speeds, the valve-timing must be changed. Compared with the standard engine, this change consists of opening and closing the inlet valve later, the exhaust valve opening earlier and closing later. As this must be done without impairing the idling ability of the engine, it is at best a compromise.

Fig. 1 shows what has been done with a four-cylinder engine having a 4¼-in. bore and a 5-in. stroke. The tim-

[1] M.S.A.E.—Engineer, gasoline-electric design, International Motor Co., Long Island City, N. Y.

ing change raised the power developed from 53 to 56½ b.hp. at 2000 r.p.m., the lowest point of the fuel-economy curve shifting also from 1300 to 1600 r.p.m. By using a slightly larger carbureter, the peak of power was further raised to 57½ hp. at 2000 r.p.m. Due to the fact that under no conditions does the engine-speed ever drop below its maximum-torque point, a fixed or automatically advanced spark-position can be used, thus simplifying engine control. In later designs the engine-speed regulation is as close as 200 to 300 r.p.m., which means that the compression-ratio can be increased slightly without causing knock, thus again raising the peak of power. Another possibility would be to employ some form of mild supercharging, or rather "full-charging" if it may so be called, to overcome frictional and pumping losses through the inlet manifold and the valve passages. This can be done by using a small supercharger interposed between the carbureter and the cylinders. Its function should be to supply a perfectly distributed cold mixture, thus doing away with vaporizers or special hot-spot manifolds and maintaining a volumetric efficiency of 100 per cent. Besides the gain of power proportional to the increase in velocity, the thermal efficiency, and therefore the fuel economy, would be improved.

It seems logical to suggest that this "full-charger" be driven by a small electric motor using current from the main generator or some electrical source other than the battery. Due to the necessarily high rotative-speed of its impeller, its successful application depends upon the reliability of its drive. Any form of mechanical drive must be planned and designed carefully, as the operating speed-range of the supercharger renders its mechanism very sensitive to any high-frequency torsional vibrations which are always present in any form of crankshaft or camshaft drive.

Engine lubrication also becomes one of the most important problems because, unlike the mechanically driven motorcoach, the load when once applied on the engine is not relieved until a stop is made. With the mechanically driven motorcoach, the bearing loads are temporarily relieved each time a shift is made, thus flushing the bearings. With high-pressure lubrication this means a tendency to pump oil and is perhaps one of the reasons that oil consumption is less in some cases with the electric drive.

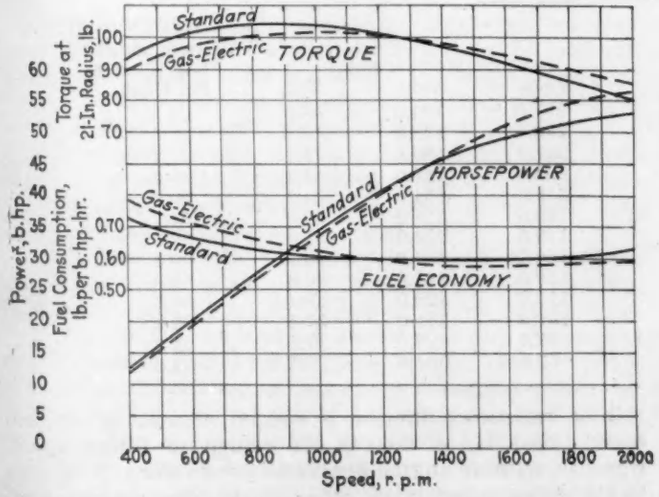


FIG. 1—COMPARATIVE TESTS OF MANIFOLDS AND CAMSHAFTS
Curves for Torque, Horsepower and Fuel Economy in Pounds per Horsepower-Hour Are Shown. The Results When Using Standard Equipment Are Shown by the Full Lines and Those When Using the Electric-Drive Engine Are Shown in Dash Lines

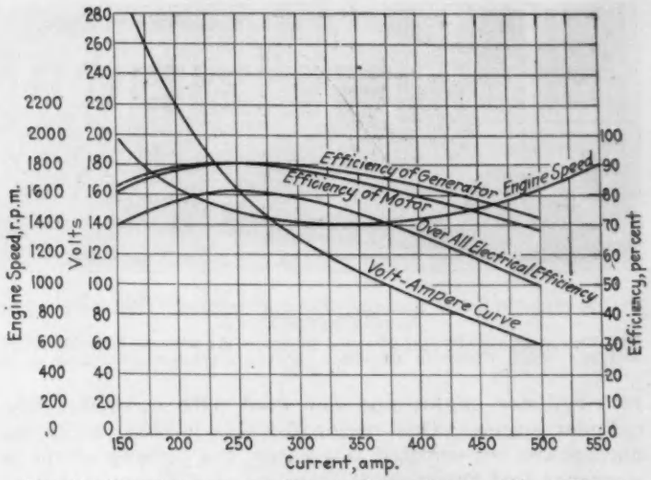


FIG. 2—VOLT-AMPERE AND ENGINE-SPEED CURVES WHEN USING ELECTRIC DRIVE

The number of cylinders bears no relation to smoothness of driving torque and is more a function of the size of the vehicle. For the larger vehicles it is preferable to use six-cylinder engines because of ground-clearance and visibility limitations. The evenness of torque which characterizes the electric drive can be understood best by comparing the number of power impulses per revolution of the rear driving-wheels for both types of drive.

Assuming a four-cylinder four-cycle engine having a mechanical gearbox low-gear ratio of 4.8 to 1.0 and a rear-axle ratio of 6.7 to 1.0, which is a suitable ratio for city work, we have 63 impulses per wheel-revolution. The same chassis equipped with an electric drive having a motor with 33 commutator bars and a 10.79-to-1.00 gear-ratio will give 356 power impulses per wheel-revolution. This is to say that, theoretically, the smoothness of operation will be in the ratio of approximately 5½ to 1, or, forgetting efficiency for the time being, the electric drive will exert its maximum propulsive effort at a road speed one-fifth of that of the mechanically driven motorcoach because the flow of current evens-out all power impulses of the engine; however, it is not wholly true actually, on account of the frictional work done by the clutch on the mechanically driven motorcoach, which work is difficult to estimate accurately.

INSTALLATION AND WEIGHT CONSIDERATIONS

To obtain a satisfactory installation it is necessary that the electrical units be balanced properly with the rest of the chassis. Here, again, a compromise must be reached between the maximum vehicle-speed and electric-motor speed. Present-day commutator-designs impose a limit somewhere around 9000-ft-per-min. peripheral speed for the armature; ground-clearance and weight limit the size of the motor; and the combination of all these limits the gear-ratio and, therefore, the maximum vehicle-speed.

The generator and motor armatures should be as light as possible to reduce "flywheeling" to the minimum. The necessary ground-clearance and body-floor obstruction limit their respective diameters. Due to its high rotative-speed the motor armature should be of smaller diameter than the generator armature, thus producing less inertia-effect because the coils of copper which constitute the bulk of its weight are always near the periphery.

The weight of an electric drive varies almost proportionately with the horsepower it must transmit. This is not true with the standard gearbox, as there is no great difference in weight between a gearbox used with a 60-hp.

FIG. 3—SIX-CYLINDER ELECTRIC-DRIVE MOTORCOACH EQUIPPED WITH SINGLE-MOTOR DRIVE

Ventilation of the Pocket Formed between the Frame Side-Members and the Body Floor Is Provided by the Vertical Air-Ducts at *A*

four-cylinder engine and one used with a 100-hp. six-cylinder engine. One reason for this is that, while the horsepower transmitted is greater, the turning effort is smoother and this permits the use of a lower factor of safety.

GENERATOR AND MOTOR EFFICIENCIES

If we calculate and plot the efficiency of the generator and motor of an electric drive derived from readings taken at various motorcoach-speeds and combine them, we have a set of curves such as those shown in Fig. 2. I speak particularly of a single-motor testing-installation on a 29-passenger motorcoach that weighs slightly more than 19,000 lb. with a 29-passenger load and is powered with a six-cylinder 4¼ x 5-in. engine which develops 91 b.hp. at 2000 r.p.m. It can be observed that, as the speed of the vehicle rises, the current falls and the over-all efficiency drops. The same holds true under severe overloads such as occur when starting in deep sand or mud. In this case a self-excited shunt-wound generator is used that has a small teaser-field supplying the starting excitation, and the core losses due to high voltage at high vehicle-speed reduce its efficiency from 90 per cent at 13 m.p.h. to about 81 per cent at 35 m.p.h., or a loss of 9 per cent.

It is to be noted that the efficiency curve of the motor falls off rapidly with an increase of voltage and that, under heavy loading, such as occurs immediately when starting, it may drop below 65 per cent. Table 1 gives the dynamometer readings used to plot the volt-ampere and engine-speed curves of Fig. 2. The over-all-efficiency curve shown represents, therefore, the efficiency of the volt-ampere curve. Table 2 is a brief compilation of road-test readings. A comparison of Tables 1 and 2 shows a differential figure for horsepower, which is due to the fact that the dynamometer-test data were obtained under very poor ventilation conditions and without any change in carbureter adjustment, resulting in low volumetric-efficiency and an unduly rich mixture.

With a further increase in vehicle speed and, therefore, increase in voltage, the motor curve falls off rapidly. The logical conclusion is that the field of operation of this combination lies between these two extremes, which closely represent city-service work. It is to be conceded that these units were designed for this particular kind of service, and have, relatively speaking, an armature core consisting mostly of copper to keep losses at the minimum under heavy loading. The opposite, that is, more iron and less copper, would be more suitable for interurban work to reduce potential or core losses, but this must be done at the expense of torque.

COMPARISON WITH STANDARD TRANSMISSION

The corresponding efficiency of the standard transmission for the same type of motorcoach varies from 88 per cent on low gear to 95 per cent on high gear and is fairly flat throughout the speed range, as the only losses that are met with are the tooth-rolling and bearings losses, which are very small, and the oil churning, which varies with the grade of lubricant used and the ambient temperature.

With reference to the chassis, it is important that the exhaust piping be located outside of the frame side-members to eliminate undue radiation of heat to the electrical units. Ventilation of the pocket formed between the frame side-members and the body floor should be provided. One way of doing this is by vertical air-ducts, such as those indicated at *A* in Fig. 3, connecting the cowl and the floor so that cold air will be forced under the body by the forward motion of the vehicle while, at low speeds, the reverse will occur, that is, the warm air will rise. Generator and motor covers should be made easily accessible for periodic inspection of the commutator brushes and windings.

TORQUE INSULATOR AND ELECTRIC BRAKING

It has been found necessary to interpose in the generator drive a cushioning device such as is shown in Fig. 4 to absorb, temporarily, the horsepower that is being delivered at the time the throttle is suddenly closed prior to making a stop. When this occurs with a mechanical transmission, the inertia of the vehicle as a whole and its rolling resistance impede a sudden change of engine-speed; that is, it retards its return to idling speed, whereas, with an engine-generator group alone, it returns to its idling speed much more quickly because the generator armature offers no resistance beyond that of its own inertia and therefore the same amount of power must be absorbed in a shorter time. This particular cushioning device is called a torque insulator and consists

TABLE 1—DYNAMOMETER-TEST DATA

Vehicle Speed, M.P.H.	Rear-Wheel Power, Hp.	Engine-Speed, R.P.M.	Calculated Power, B.Hp.	Generator Output			Calculated Over-all Efficiency, Engine to Rear Wheels, Per Cent
				Volts	Amp.	Kw.	
35.60	20.0	1,915	76.0	291.0	160.0	46.5	26.3
30.70	30.6	1,800	71.8	262.5	172.0	45.2	42.6
28.70	31.3	1,765	70.5	251.0	180.0	45.2	44.4
26.10	33.0	1,715	68.7	236.0	188.0	44.3	48.2
22.70	34.3	1,640	67.3	216.0	204.0	44.2	50.9
20.00	35.0	1,585	64.5	198.0	216.0	42.8	54.2
17.00	36.2	1,525	61.2	179.0	234.0	41.9	59.1
14.20	36.4	1,480	60.5	160.0	254.0	40.7	60.1
11.30	36.4	1,440	59.8	140.0	285.0	40.0	60.8
8.33	34.9	1,415	58.5	117.0	328.0	38.4	59.6
6.36	33.6	1,420	59.0	101.0	371.0	37.4	56.9
4.82	32.6	1,470	62.7	87.5	428.0	37.5	52.0
2.22	18.0	1,240	55.2	59.0	504.0	29.7	32.6

TABLE 2—ROAD-TEST DATA

Vehicle Speed, M.P.H.	Engine-Speed, R.P.M.	Generator Output Volts	Amp.	Kw.	Calculated Power, B.Hp.	Time, Sec.
		Acceleration Test with 29-Passenger Load				
4.5	1,500	90	420	37.8	62.6	2.9
8.9	1,600	138	360	49.8	77.6	5.0
13.4	1,550	166	290	48.2	72.6	8.2
17.8	1,580	194	248	48.2	72.0	13.6
22.3	1,700	226	220	49.8	75.0	24.0
26.7	1,780	250	195	48.8	74.4	37.0
30.3	1,810	268	184	49.4	77.0	52.0
		Measurements on Beacon Hill, Long Island, N.Y.[1]				
10.7	1,750	150	340	51.1	77.8	...
11.6	1,700	148	342	50.6	77.4	...
9.4	1,695	134	360	48.2	75.0	...

[1] Weak generator-field with second resistance-step cut-in, 29-passenger load.

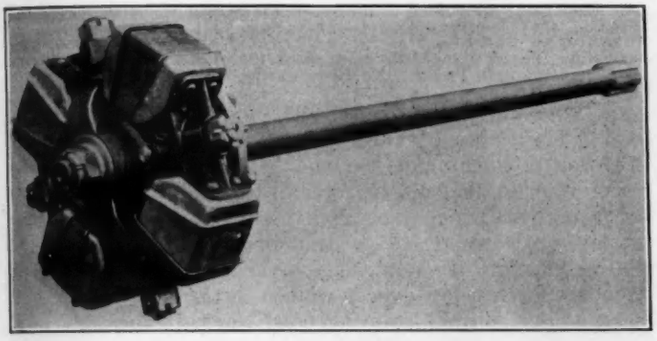


FIG. 4—TORQUE INSULATOR

The Device Consists of Four Rubber Blocks Held in Position by Eight Cups Which, in Turn, Are Held in Place by Four Arms. These Arms Are Bolted upon Two Spiders, One Driving the Other through the Rubber Shock-Insulators. The Device Prevents Transmission to the Generator of High-Frequency Vibrations Such as Occur in Any Engine and Eliminates Synchronism of Such Vibrations between the Two Units

of four rubber blocks held in compression by eight cups which, in turn, are held in place by four arms. These arms are bolted upon two spiders, one driving the other through the rubber shock-insulators.

Other important functions performed by the torque insulator are prevention of transmission to the generator of high-frequency vibrations such as are found in any engine, and elimination of any possible synchronism of such vibrations between the two units.

To overcome the lack of engine braking when coasting down hill, use is made of the electric motor to hold the vehicle on a down grade by reversing its field and connecting a resistance in the circuit. When the electric brake is used constantly as a preliminary service-brake, the capacity of the electric motor must be increased from 20 to 25 per cent more than necessary for driving because of this added work which is required of it, and this means a heavier and costlier motor.

Dynamometer tests, illustrated in Fig. 5, have shown that engine braking equals 10 hp. at 15 m.p.h., 15½ hp. at 20 m.p.h. and 20 hp. at 25 m.p.h. If we deduct from these figures 0.5, 1.0 and 1.5 hp. respectively, representing the amount of braking done by the electric-motor fan, we have the net energy to be absorbed either by electric braking or the additional work required of the brakes. The electric-brake resistance-grids generally used must have sufficient capacity to absorb the kinetic energy of the vehicle, and their temperature should not exceed 600 deg. cent. (1112 deg. fahr.) under extreme conditions because, being made primarily of cast iron, they are more or less sensitive to vibration.

ADVANTAGES AND DRAWBACKS

It has been fairly established that the greatest asset of the electric drive as applied to the motorcoach is the permissible increase in schedule speed where traffic is congested. Its smoothness of operation unquestionably has made it very popular with passengers and the claim has been made that this quality has increased revenues in certain localities. Any increase in schedule speed means a reduction of operating expense per mile, together with a reduction of capital investment and maintenance costs.

Other advantages of the electric drive are its quietness of operation due to the elimination of the selective-gear-shift transmission and its extreme ease of operation, as the driver has but two operations to perform in addition

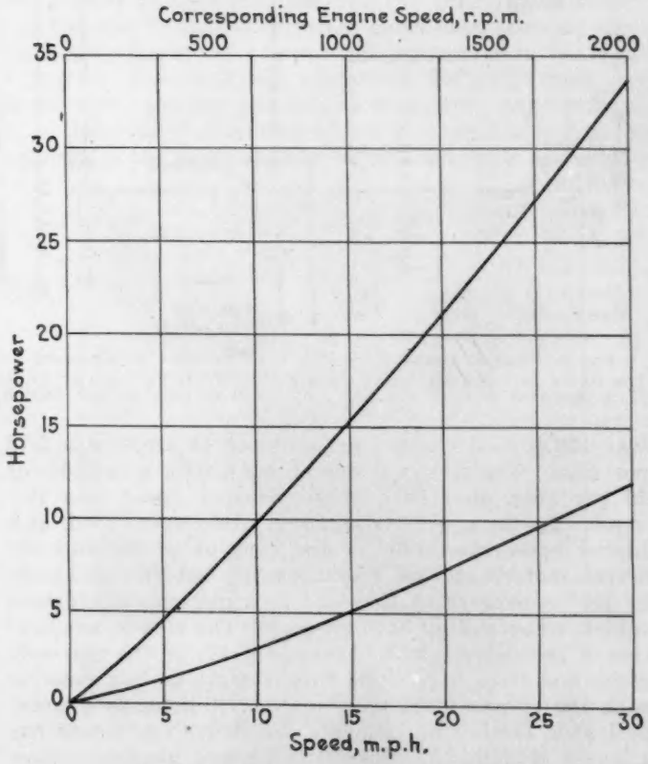


FIG. 5—RESULTS OF DYNAMOMETER TESTS

The Upper Curve Shows the Braking Effect of the Motor When Running on High Gear with Throttle Closed. The Idling Speed of the Engine with Spark Advanced Is 280 R.P.M. The Lower Curve Shows the Braking Effect of the Tires, Rear Axle and Transmission with Gears in Neutral. The Data Are for a 29-Passenger City-Type Motorcoach, Not Loaded, Using 34 x 7-In. Tires and a Rear-Axle Ratio of 6.70 to 1.00

to steering; that is, the operation of the accelerator pedal with his right foot and the operation of the service brake with his left foot. There is reason to believe that this ease of handling promotes safety because the attention of the operator is not distracted by gearshifting. Electric-drive control permits constant duplication of performance, irrespective of the driver. This means, to a certain extent, greater regularity of headways and schedules. With single-deck, one-man-operated motorcoaches, the elimination of the gearshift lever renders fare collecting much easier, saves time and lessens the physical fatigue and mental strain on the driver. This can be readily appreciated by mentioning the results of a check made on a city-run with a motorcoach in actual operation for a full day. The total number of miles

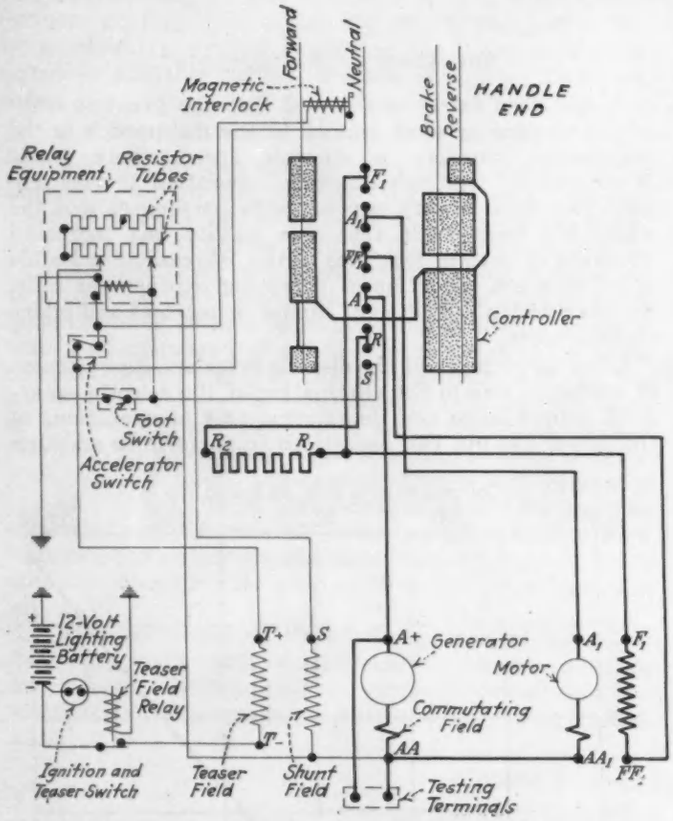


FIG. 6—WIRING DIAGRAM OF THE SIX-CYLINDER MOTORCOACH
The Relay Interposed in the Teaser-Field Circuit To Open or Close It Is Operated with the Battery Current from the Ignition Switch

was 156.60 and the average number of stops was 5.75 per mile. The total number of gearshifts was 3140, or 20 per mile, and the average schedule speed was 10.1 m.p.h. As the engine is running, while under load, at a higher speed-rate than in the case of a mechanically driven motorcoach, its vibrations are not felt so keenly by the passengers as they are in a mechanically driven vehicle when pulling on high gear. The steady acceleration of the electric drive eases the strain on the rear-axle gears and tires and, while this is more or less possible with the conventional transmission, it depends a great deal upon the human element. Electrical equipment has a longer economic life than clutches and gearboxes have when used constantly in dense traffic. Its maintenance problems are familiar to street-railway operators who understand electric power thoroughly.

At present, some disadvantages of the electric drive exist which have the effect of limiting its adaptability to

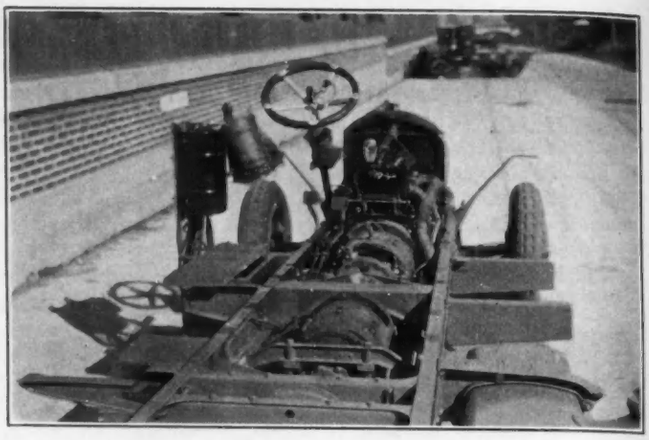


FIG. 7—FOUR-CYLINDER MOTORCOACH CHASSIS
The Generator Is Bolted Directly to the Flywheel Housing of the Engine, the Complete Power-Generating Unit Being Mounted on Five Rubber Shock-Insulators, One Located at the Front End, Two on Either Side of the Engine and in the Plane of the Torque Reaction and Two at the Rear of the Generator

very specified and defined fields. Its higher initial cost, which is close to 20 per cent of the price of a complete motorcoach, commands serious consideration. It weighs from 1250 to 1650 lb. more than the conventional clutch and gearbox, which means that more pounds per horsepower must be carried as dead-weight.

The electric drive is yet comparatively inefficient for vehicles having low power-weight ratio. We have seen that, under normal running conditions, its best over-all efficiency is in the neighborhood of 80 per cent and is reduced under heavy-load conditions to as low as 50 per cent. These inefficiencies do not become apparent unless accelerating beyond 1000 ft. or climbing long steep grades without stops. The reason is that, first, the time lost in changing gears with mechanical transmission is sufficient to overcome the difference in time due to the lesser power transmitted to the rear axle by the electric drive. In the second case it is due to the inertia of the engine and generator. There is a slight time-lag at the start of acceleration which is caused by the necessity of building up the necessary magnetism and potential in the generator. The time loss, however, does not become serious until traffic conditions call for 15 or more stops per mile.

Fuel consumption is greater with the electric drive. Lack of operating data has not yet permitted accurate comparison of its cost of maintenance with that of the

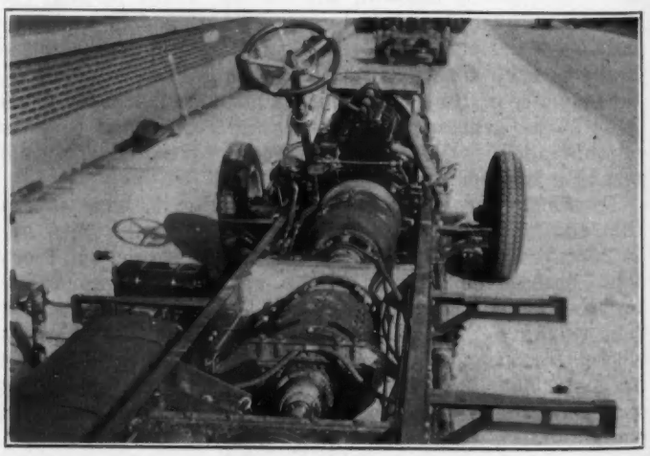


FIG. 8—SIX-CYLINDER MOTORCOACH CHASSIS
The Engine and Generator Are Mounted Separately, the Engine Mounting Consisting of Four Shock-Insulated Points and the Generator Mounting Being Similar

mechanical transmission, but assuming ideal conditions over a period of 8 to 10 years, there should be no great difference between the two. It is owing to lack of technical knowledge that individual operators regard the electric drive with skepticism.

Recent Developments

For the last 2 years the company with which I am connected has tested and developed, in conjunction with the General Electric Co., an electric drive which has been properly sized for a four-cylinder 57½-hp. 25-passenger motorcoach and a six-cylinder 90-hp. 29-passenger motorcoach. It is of the single-motor type because it is felt that the complications involved with a two-motor drive did not warrant the only advantage derived, which is the return to the garage or car-house of a motorcoach with one motor when the other is "dead." This applies only to four-wheel single-deck motorcoaches. With a double-deck motorcoach weighing in excess of 12 or 15 tons, we are confronted with a different problem and the two-

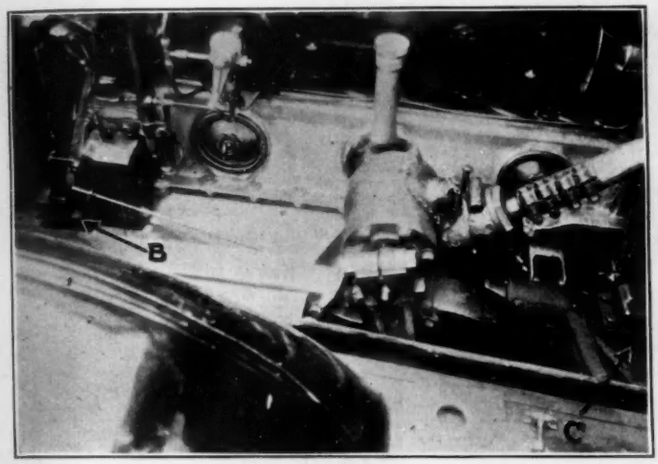


Fig. 9—Shock-Insulated Powerplant Mounting
Two of the Shock Insulators Are Shown at *B* and *C*

motor drive becomes a necessity if platform height is to be kept at the minimum and still retain adequate ground-clearance.

The simplicity of the single-motor drive is commendable, because it often accompanies reliability. It is lighter, and lightness is still one of the primary requirements of motorcoach design, as performance depends upon weight per horsepower. With snow and ice on the ground, spinning of one of the driving wheels due to lack of road adhesion is less evident because of the smoothness of the electric-motor torque. The location of the motor between the frame side-members protects it from water, dirt and dust, and also affords maximum ground-clearance. The use of the conventional type of rear axle reduces the unsprung weight and keeps frictional resistance to the minimum. Low unsprung-weight also means greater tire mileage. It is also possible, by interposing a driveshaft brake between the motor and the rear axle, to equalize the braking effort of the rear wheels through the differential and to minimize skidding on slippery pavements. This is not readily possible when a motor is used to drive each rear wheel independently, because, when the vehicle is being "braked," no power flows through the motors.

General Features

Speaking of the electric drive generally, the type of generator used on both models is a self-excited machine. It was felt that a separate exciting-generator was unnecessary, as a sufficient amount of initial excitation can be obtained by connecting the teaser field of the generator in series with the standard 12-volt starting and lighting battery. By the elimination of the exciters the generator weights were reduced, the machines shortened and maintenance lessened. The current consumption of the teaser field in the four-cylinder motorcoach is approximately 1 amp. continuously, because the circuit is interconnected with the ignition switch; in other words, the teaser-field circuit is closed so long as the ignition is on. On the six-cylinder motorcoach the current consumption is 10 amp. and, as constant drain of the battery at this rate would require an increase in its size, a potential relay has been provided to break the circuit at a predetermined voltage. Actual tests have shown that, in the latter case and in city service, the teaser field stayed "on" 20 per cent of the total schedule-time; that is, the current consumption amounted to 2 amp. per hr. With a 10-amp. discharge-rate, it was impossible to connect the circuit directly to the ignition because the reactance voltage might require a switch of much larger capacity, so a relay was interposed in the teaser-field circuit to open or close it. This relay is operated with the battery current from the ignition switch and is illustrated on the wiring diagram of the six-cylinder motorcoach shown in Fig. 6.

The series motor has interpoles or a commutating field in series with the armature. The function of the interpoles is to build up a counter electromotive-force to oppose the one that flows through the coil temporarily short-circuited by the commutator brush before the latter opens the coil circuit by passing over that particular commutator bar, thus preventing arcing. Other features which are similar in both the four and the six-cylinder motorcoaches are, first, the complete shock-insulation of each unit individually to prevent the transmission of high-frequency low-amplitude vibrations not only from one member to another but to the passenger compartment. It is this type of vibration which is so detrimental to the comfort of the rider and the life of the vehicle as a whole.

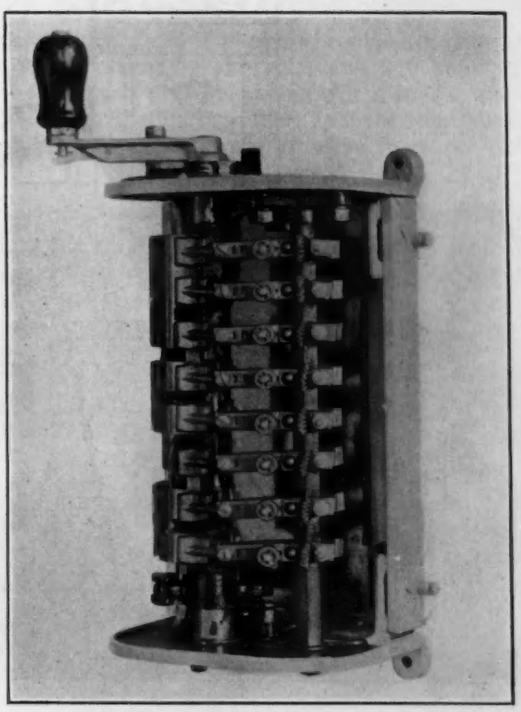


Fig. 10—Electric-Drive Controller

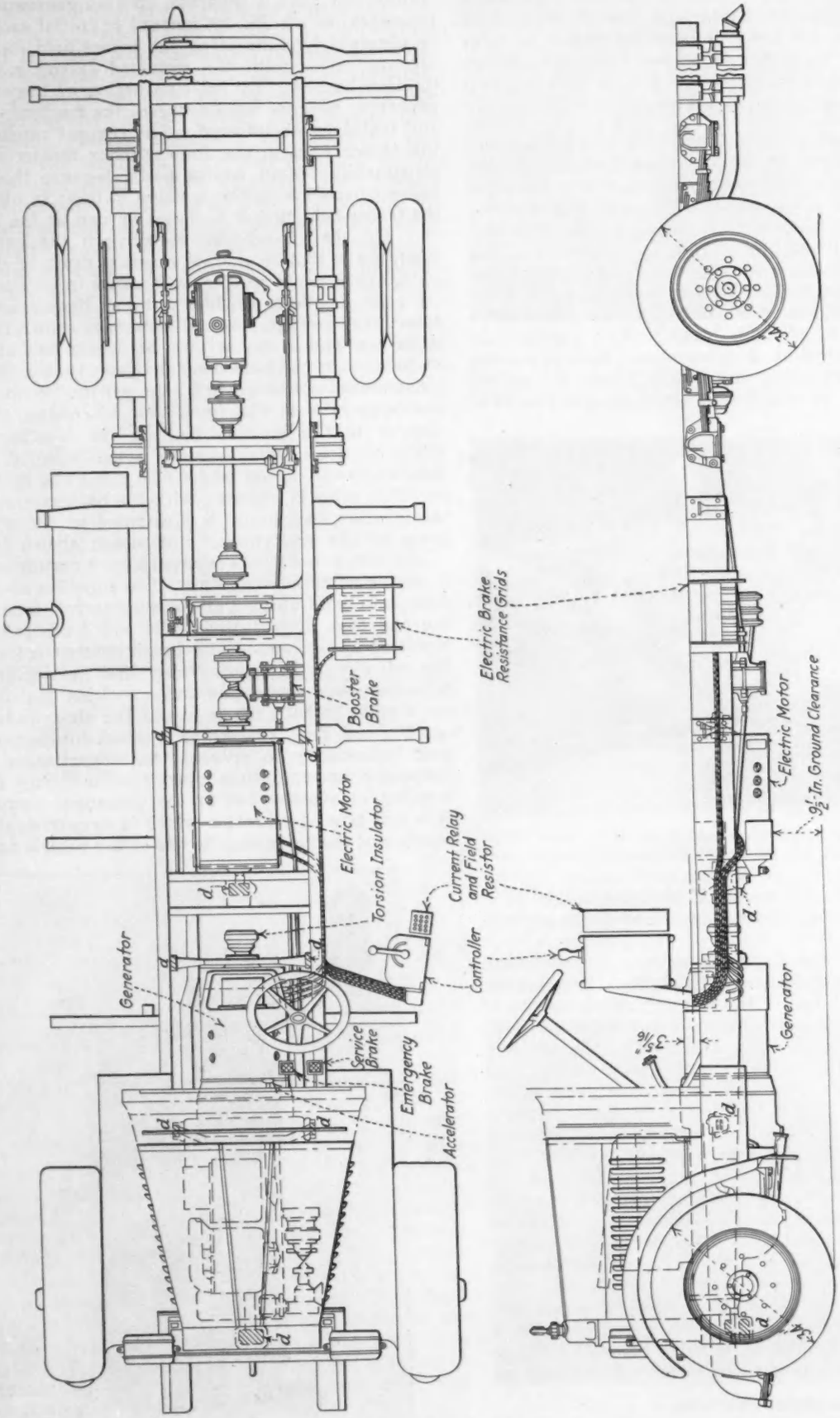


FIG. 11—ELECTRIC-DRIVE FOUR-CYLINDER CHASSIS

The Engine and Generator Are Mounted on Five and the Electric Motor on Three Rubber Shock-Insulators, Indicated by *d*, at the Respective Locations

In the four-cylinder motorcoach shown in Fig. 7, the generator is bolted directly to the flywheel housing of the engine, the complete power-generating unit being mounted on five rubber shock-insulators, one located at the front end, two on either side of the engine and in the plane of the torque reaction and two at the rear of the generator supporting the trunnion bearing.

In the six-cylinder motorcoach shown in Fig. 8, it was deemed advisable to mount the engine and generator separately, the engine mounting consisting of four shock-insulated points, two of which are shown at *B* and *C* in Fig. 9, the generator mounting being similar. The electric-motor mounting, in both cases, is of the three-point type; one rubber insulator supports the commutator end and two mounted at the pinion end take the torque reaction. The springs are rubber shock-insulated. Other parts that are insulated from shocks and vibrations are the radiator, the steering-column, the steering-wheel, and the gasoline tank. The controller, shown in Fig. 10, is handily mounted on both models on the left side of the driver within easy reach. The emergency-brake lever, which is conventional with mechanically driven motorcoaches, has been eliminated and a pedal substituted which is operated by the driver's right foot; it is provided with a ratchet to permit locking when parking. The left pedal actuates the service brake, operative on the rear wheels through a well-known vacuum-brake cylinder.

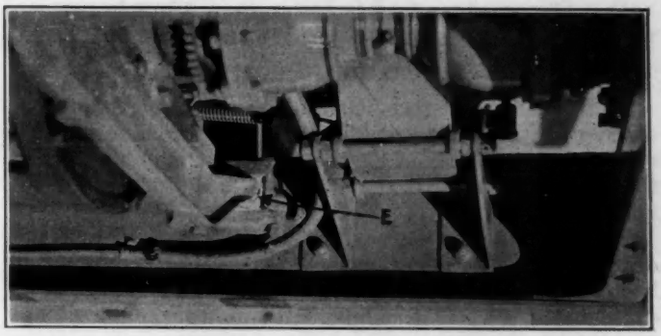


FIG. 13—REAR SUPPORT FOR ELECTRIC-DRIVE MOTOR
Note the Rubber Mounting on the Frame, Indicated at *E*

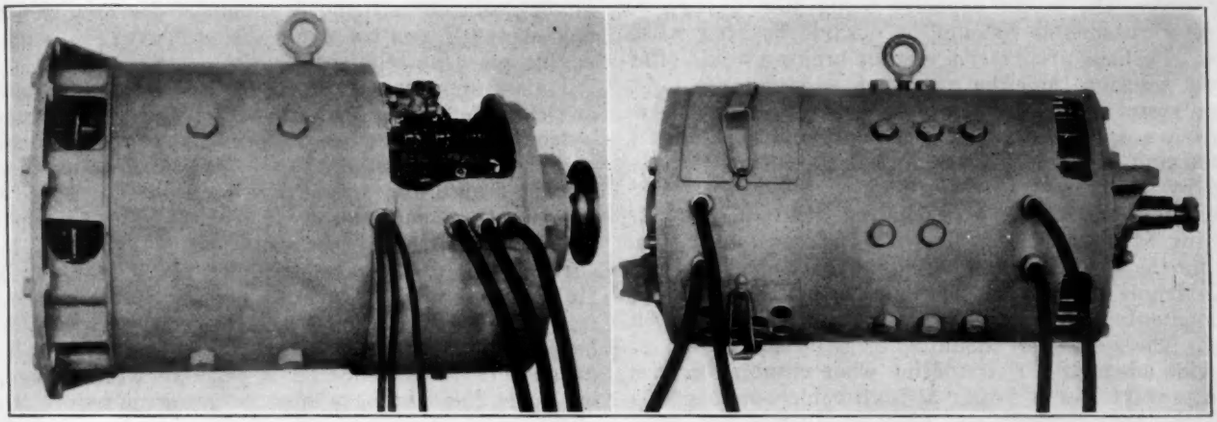


FIG. 12—ELECTRIC-DRIVE COMPOUND-WOUND GENERATOR AND SERIES MOTOR
The Generator, Shown at the Left, Has a Rating of 125 Volts and 200 Amp. at 1200 R.P.M. The Motor, Shown at Right, Is Rated at 125 Volts and 140 Amp. at 1100 R.P.M.

Fig. 11 shows the four-cylinder chassis, the respective locations of the shock insulation being indicated by *d*. The compound-wound generator shown at the left in Fig. 12 has a rating of 125 volts and 200 amp., or 25 kw. at 1200 r.p.m. It has a small series-field accumulatively connected and weighs 727 lb. complete. The series motor shown at the right in Fig. 12 is rated at 125 volts and 140 amp. at 1100 r.p.m. and its weight is 610 lb. Fig. 13 illustrates the rear support of the motor, which is bolted to the pinion-end cover and takes the torque. Note the rubber mounting on the frame, indicated at *E*. At the front, the rubber block is located on the exact center line of the motor so as to eliminate any bending movement on the support. A two-step current-relay located alongside the controller is used to weaken the generator field automatically when accelerating or climbing a hill. Its function is to speed-up the engine to deliver more horsepower and therefore more kilowatts when conditions require it.

The six-cylinder-chassis generator shown in Fig. 14 is of the shunt-wound type. It has a rating of 190 volts and 200 amp. or 38 kw. at 1400 r.p.m. and weighs 1000 lb. As it, as well as the engine, is mounted on rubber, two torque-insulators, one at each end of the driveshaft, connect its quill shaft and the engine crankshaft. The electric motor has a rating of 190 volts and 240 amp. at 1880 r.p.m. Its power, or 1-hr. rating, for a temperature rise of 75 deg. cent. (167 deg. fahr.) is more than 80 hp. and it weighs 800 lb. The acceleration performance obtained

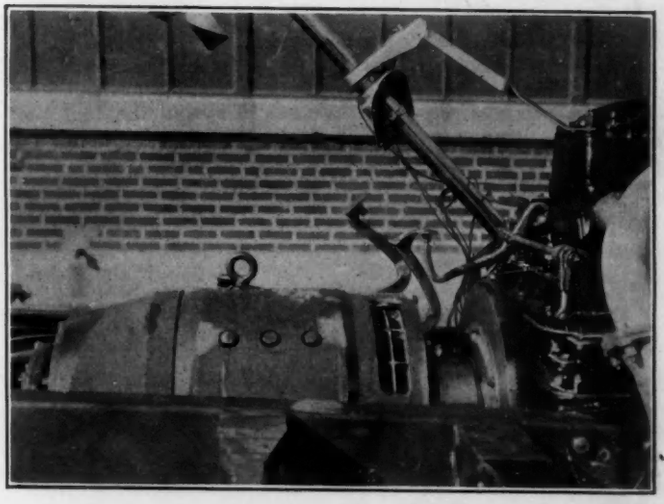


FIG. 14—GENERATOR FOR ELECTRIC-DRIVE SIX-CYLINDER CHASSIS

with a 30-passenger load is better than 1 m.p.h. per sec. up to 25 m.p.h. and 2 m.p.h. per sec. up to 15 m.p.h.

Future Developments

To forecast what the ultimate electric drive for motor-coach work should be would be presumptuous but, without joining the army of crystal gazers, it may be possible to predict the trend it should follow from an automotive viewpoint.

First, to simplify service problems, it would be highly desirable that the generator, the motor and the controller be assembled into one unit and preferably mounted in the chassis at three points. One point would form a trunnion support at the front end of the generator and a cross member or supporting brackets at the motor end would take the torque. This construction would form a self-contained unit, integrally wired, which could be replaced quickly in case of failure and without the employment of skilled labor.

For total weights, that is, chassis, body and pay-load, not exceeding 10 to 12 tons, it should be of the single-motor drive, the motor capacity being just enough to provide a reasonable amount of electric braking when needed. Perhaps progressive electric braking would offer a better solution than the present fixed-resistance type. To go a step farther, it could be operated by a pedal connected to a special braking controller, and the present forward and reverse driving-controller positions be obtained by a switch.

There is a possibility of excluding dirt and dust by designing a combination unit with enclosed ventilation, by using the space between the units themselves and the chassis frame in the form of air tunnels, made of high heat-conductivity material such as aluminum and well ribbed. The single fan should be on the generator shaft to provide adequate air-circulation when climbing grades and to prevent loss of power at high vehicle-speeds. To obtain greater efficiency, and when production will warrant it, frames could be laminated, just sufficient iron being used to meet the magnetic-circuit requirements, the rest of the structure consisting of aluminum and alloy steels liberally used; in other words, automotive materials. The controller should be provided with interlocking means to prevent the inexperienced or uneducated driver from shifting the handle and causing damage.

Of equal importance, the development of high-heat-resistivity insulation would allow further reduction in size, weight and perhaps cost of equipment. It would help the enclosed self-ventilation scheme already mentioned by providing a higher temperature-difference with the ambient air. The present shunt-wound generator and series-wound motor can be improved by further study of windings. I admit that it is difficult to improve on the series-wound motor, but its efficient speed-range is limited. So far as efficiency is concerned, present generators leave room for improvement, and it may be that compound-wound generators offer possibilities not heretofore appreciated.

For interurban work perhaps a smaller self-contained unit having a direct clutch, current operated, may prove more satisfactory, or, following the present independent motor-generator scheme, a manually-operated generator field-strength control could be employed to vary the engine-speed as required.

I am fully aware that all these remarks are open to criticism, but I feel that constructive criticism is always welcomed by anyone whose mind is open on the subject and that in the past it has always served as an index to correct design and progressive application. There is no question that there is a great deal yet to be accomplished before we can talk of standardization and that, in the current state of the art, any improvement is a step in the right direction. I believe the present status of the electric drive is that it has reached the point where it will have to stand or fall on its economic merit. Its inherent advantages have rendered it popular with passengers, but some disadvantages must be overcome before it completely wins the confidence of the operators and claims the place it rightly deserves on principle in the field of automotive transportation.

OUTPUT PER MAN-HOUR

THE United States Bureau of Labor Statistics has prepared some interesting studies of the increase from 1914 to 1925 in man-hour productivity for 11 manufacturing industries. The Bureau has specifically warned against uncritical acceptance of the results, because of the unsatisfactory character of many of the data used and the fact that 1914 was a year of depression, while 1925 was a very active year. The figures are nevertheless of considerable interest as a measure of what is going on in American industry. They are summarized below:

Industry	Increase, Per Cent
Automobiles	172
Boots and Shoes	6
Cane Sugar Refining	28
Cement Manufacturing	61
Flour Milling	40
Iron and Steel	59
Leather Tanning	26
Paper and Pulp	34
Petroleum Refining	83
Rubber Tires	211
Slaughtering and Meat Packing	27

Affording some light on the necessary allowance for such warping effects as depression in 1914, *The Iron Age* estimates that the actual increase in productivity per man-hour in the iron and steel industry was probably about 27 per cent from 1914 to 1925.

The implications in this increase in potential industrial output are infinite, and many important questions are raised. Thus, it is the fashion in Europe to decry the so-called "standardization of American life" and other consequences of our manufacturing methods. But it is at least fair to inquire whether such criticisms do not emanate in the main from sources that have not as yet become adjusted to the concept of economic democracy as the term is generally understood in the United States.

So great has been the increase in output per worker since the rise of modern industry that a gradual reduction in the hours of labor has been possible in most countries and lines of endeavor, this reduction being accompanied by a fairly consistent rise in the standard of living. It is not unlikely that the increase in recent years in the productivity per unit of labor in the United States eventually will result in a further shortening of the working time required to provide the population of the Country with necessities and luxuries. In the light of experience, such a trend cannot be regarded as otherwise than economically sound.—*Commerce Monthly.*

Gasoline—Past, Present and Future

By A. Ludlow Clayden[1]

Buffalo Section Paper *Illustrated with* Drawings and Photograph

EXPLOITATION of natural resources goes through four stages: (*a*) discovery, (*b*) utilization, (*c*) shortage of the raw material, and (*d*) discovery of means to maintain a requisite supply or its equivalent. Gasoline has passed rapidly through the first three stages and is now well advanced in the fourth stage. By 1930 we shall no longer be dependent upon natural raw gasoline. As has occurred with other products, gasoline of the future will be a much superior article.

Materials are improved by application of labor or mechanical power, which increases the cost; hence improvement in methods of utilization must be made concurrently.

The only present possible original sources of supply of motor fuel are petroleum, coal and vegetation. The cost of manufacturing any large yield of gasoline equivalent from coal or vegetation is prohibitive, and petroleum probably will remain the major source of supply for the next 50 years. The controlling factor in the price will be the cost of getting it from the ground and transporting it.

Methods of deriving gasoline from crude petroleum are reviewed by the author, who refers to difficulties encountered by the automobile-engine builder with starting, crankcase-oil dilution and detonation that led to adoption of Government specifications. Recent work has shown, however, that the distillation test is only a rough indication of volatility and that two gasolines that meet the specifications may not perform similarly in an engine. At present, the only means of economizing gasoline is to increase engine compression. This introduces detonation, but a rapidly increasing proportion of our gasoline supply is produced by cracking processes. It is possible so to control these that the product is richer in antiknock constituents.

Discussion of the paper brings out that it is possible with some engines to increase the mileage per gallon almost as much by increasing compression as by the use of antiknock fuel, without noticeable increase of detonation even with the usual run of gasoline; that the distillation method of determining volatility is unsatisfactory, as fuels having the same end-points by this test may have dew-points differing by 20 deg. fahr. or more. A fuel having volatility at low temperature is needed for starting a cold engine, while with engines having highly heated intake-manifolds best results are obtained in continued operation with a fuel of low volatility at high temperature. As a compromise, a fuel of practically constant volatility under all operating conditions would be ideal. If a fuel of 450 deg. end-point by the distillation test can be used generally, it will enable the refiner to make a deeper cut into the crude and will be satisfactory if it has sufficient volatility at low temperature.

MOST things that make the difference between civilization and savagery are, in the broadest sense, mechanisms. The mental development that marks the difference between the aborigine and the civilized man would have been impossible had man failed to discover how to direct and utilize the forces of nature, how to exploit the potential energy of the earth beneath his feet.

Such exploitations almost always go through four stages, sometimes rapidly and sometimes very slowly. First comes the discovery of a material; second, the uses to which that material can be put; third, the shortage of the raw material, and fourth, the discovery of how to maintain a requisite supply of the raw material or its equivalent. A simple example is building materials: First, stone; then walls and houses; then lack of stone in certain places; and, finally, the discovery of the process of making brick. Today brick and tile are so great an improvement upon natural rock that we are able to build furnaces and other structures for which any natural raw material is utterly unsuited. In textiles we are probably only in the infant stages of artificial silk and cotton. It is entirely conceivable that even within the next quarter of a century we shall discover how to make artificial threads stronger and more durable than any natural fibers. The first substitute for a natural raw material is generally a substitute in every sense, an inferior article, but after a time man usually is able to improve upon nature.

[1] M.S.A.E.—Research engineer, Sun Oil Co., Philadelphia.

Gasoline has worked more rapidly in changing conditions of living than has any other material discovered, and it is passing with unprecedented rapidity through the four normal stages of development. From the discovery of petroleum up to the year 1900, gasoline was to the refiner a troublesome waste product. Between 1900 and 1910 it became a commodity for which the demand was rapidly overtaking that for other petroleum products. By 1920 there was an alarming probability of shortage of supply. We are now well advanced in the fourth stage, and by 1930 we shall no longer be dependent upon the natural raw gasoline, which was the only thing of its kind in existence 27 years ago. Also, as has occurred with other products, gasoline of the future will be a far superior article to the original natural fluid which made possible the automobile.

Hand in hand with the improvement of the material must go improvements in methods of its utilization. Materials, in the broad sense, are improved by putting into them either labor or mechanical power, usually both, which inevitably has to be paid for. Thus, to obtain the derivable benefits of the improved material necessitates improved utilization.

Three Sources of Motor-Fuel Supply

For motor fuel we have, at present, only three possible original sources of supply: petroleum, coal and vegetation. Our original gasoline was obtained from petroleum at extremely small cost. As we obtained more and more gasoline from each barrel of crude oil, the manufacturing cost increased. With coal, the manufac-

turing cost of any large yield per ton of gasoline equivalent is, at present, utterly prohibitive, and the same is true of the manufacture of fuels of the alcohol type from vegetable sources. There is, at present, nothing to indicate any methods whereby coal or vegetation can be converted into liquid form without considerable expenditure of power; consequently, for probably at least the next 50 years, petroleum will remain the major source of supply of gasoline, and the controlling factor in the price of the fuel will be the cost of getting it from the ground and transporting it to its point of utilization. By this I mean that the manufacturing cost probably will become a smaller item in the cost of the finished product.

The original gasoline was obtained from crude oil by the application of very moderate heat, and that was practically the whole process. It provided a very light fuel of which the heaviest constituents boiled at less than 300 deg. fahr., so that when put through the simplest kind of carbureter the manifold was filled with a mixture acting in every way like a fixed gas. As the demand increased it became necessary to apply more and more heat to the original crude, which meant that more and more complex hydrocarbons were present in the gasoline, and the average boiling-point was raised. In the refinery this introduced the necessity for chemical treatments, since the higher-temperature distillation carried over with the gasoline substances of bad odor which were not colorless. For the user the engine ceased to be a true gas-engine and became a liquid-fuel engine, and all kinds of new problems of carburetion and manifolding were introduced.

Government Specifications Based on Volatility

About 1920, conditions were at their worst, both from the refining and utilization viewpoints. The refinery was faced with serious difficulty in producing enough gasoline to meet the demand, while the engine builder was faced with fuels so different from those upon which he had previously depended that the performance of his product was seriously jeopardized. To be specific, difficulty in starting, dilution of the lubricant and severe detonating tendencies all appeared together, and all looked like problems very difficult of solution. There followed immediately a great mechanical improvement in engines, and simultaneously we had an at least equally great improvement in the fuel, although this improvement has not been so rapid as the former. This is because modifications of engine design can be laid out, made, tried, and passed upon cheaply and rapidly, whereas improvements in the methods of manufacture of petroleum products present a very difficult chemical problem, call for the investment of large sums of money and require the erection of elaborate plants before they can be properly tried on a commercial scale.

Recently I saw in a rather new gasoline-manufacturing plant a cracking installation in which the reaction chamber, or cylinder in which the heat-treatment of the raw material takes place, is approximately 8 ft. in diameter and 64 ft. long and has walls 4 in. thick. It weighs 134 tons and cost 25 cents per lb. This is only one item in the plant, yet one never can be absolutely certain that the cracking process will work on a large scale by experiment on a small scale in the laboratory.

A rather important factor in gasoline development was the general adoption of specifications, which occurred mainly between 1917 and 1920. The early specifications were all evolved with the idea of compelling the refiner to furnish fuel of adequate volatility. The effect of this, coupled with war-time demands, was a considerable and rapid increase in price, although the limitations of the specifications were not entirely responsible for the price increase. For several years argument raged as to what were the best compromise specifications, that is, specifications which would assure sufficient volatility for the requirements of the automobile and at the same time not restrict the refiner so that the yield from his crude oil would be too small, and the price, therefore, too high. In this connection the Society, together with the National Automobile Chamber of Commerce and the United States Government, conducted an elaborate series of tests, and these gave fairly good evidence that gasoline of approximately present Government specifications came nearest to satisfying all requirements.

The Government specification for motor gasoline at present reads:

> When the first drop falls from the end of the condenser, the thermometer shall not read more than 131 deg. fahr.
>
> When 20 per cent has been recovered in the receiver, the thermometer shall not read more than 221 deg. fahr.
>
> When 50 per cent has been recovered in the receiver, the thermometer shall not read more than 284 deg. fahr.
>
> When 90 per cent has been recovered in the receiver, the thermometer shall not read more than 392 deg. fahr.
>
> The end-point shall not be lighter than 437 deg. fahr.
>
> At least 95 per cent shall be recovered as distillate in the receiver from the distillation.

The apparatus with which this distillation test is made is shown in Fig. 1. Recent work has shown that this test, while simple and easy to perform, is only a rough indication of volatility, and it does not follow necessarily that two gasolines, both meeting the same specification, will perform similarly in an engine so far as volatility is concerned. The Bureau of Standards, in work carried out during the last 2 years, has shown that for easy starting it is necessary to know much more about the early stages of distillation, and that more accurate observation of the detailed boiling-points of the first 20 per cent is required. Several other laboratory methods of testing volatility have been devised and some of them are theoretically and practically much better, but they require more elaborate apparatus and probably more skilled operation; consequently the present ambition is to obtain a better interpretation of the results obtainable from the conventional method of testing.

Economical Operation Requires Antiknock Fuel

Volatility, however, has very little to do with the possibilities for economical utilization of the fuel. It is necessary that gasoline should have volatility enough to enable a cold engine to start. It is also necessary that it should not contain molecules so complex that they cannot, most of them, be burned; but these are conditions that seem easy to meet.

It is inevitable that the price of coal, of metals and of crude oil will gradually increase as the labor of obtaining them increases; therefore, to maintain the balance, we must utilize these raw materials more economically. At present, the only means we have for economizing gasoline is to increase the compression of gasoline engines. This brings in the all-important characteristic of motor fuel, which is its tendency to detonate. It has often been said that non-detonating fuel gives the piston a steady push throughout its firing stroke, whereas a detonating

fuel gives a violent kick, releasing too much energy when the piston is near dead-center and too little when it is on the way down. A paper on the Ultraviolet Spectroscopy of Engine-Fuel Flames[2], by G. L. Clark and A. L. Henne, describes studies of the stages of combustion by means of the spectroscope through a quartz window in the cylinder-head and has furnished experimental proof that this picture is a true one.

No doubt it would be possible to design an engine that would operate with reasonable thermal efficiency on successive explosions of gunpowder, but it is doubtful if such an engine could be of the piston-and-cylinder type. It probably is easier to change the chemical constitution of gasoline so that its detonating tendency is reduced than it is to change the type of engine to suit the detonating fuel. Diagrams indicating just what detonation means have been shown many times, but I have recently obtained from Dr. Graham Edgar, of the Ethyl Gasoline Corporation, New York City, some exceptionally good indicator cards that are reproduced in Fig. 2.

Cracking-Control Increases Antiknock Property

More than one-half of our gasoline is produced at present by distillation from crude oil, followed by chemical or mechanical treatment for removal of small quantities of materials having bad odors or color. A rapidly increasing proportion, which probably will soon be at least one-half, is produced by subjecting the crude oil to very high temperatures, thereby converting into gasoline portions of the crude which normally would be obtained as lubricants. These cracking processes are capable of control so that the final product is richer in non-detonating or antiknock constituents. We are only at the beginning of the development of this phase of the cracking process. At present most cracking plants are being run to produce the highest possible yield of gasoline conforming to Government specification; but, while we are finding out how to vary the treatment to improve the antiknock quality, we are also discovering that fuels more volatile than those of Government specification can be produced at an insignificant increase in cost. By this I do not mean that any refiner with cracking equipment can do as he likes on volatility or antiknock quality. The equipment we have will produce only certain results, but as new equipment is installed improvements go with it. Cracking plants are not duplicated many times; almost every new one embodies some modifications tending toward both more economical operation and an improved product, so there is every reason to feel satisfied that for many years to come the tendency of gasoline will be toward a fuel suitable for steadily increasing compression and toward slightly improving volatility.

[2] See The Journal, February, 1927, p. 264.

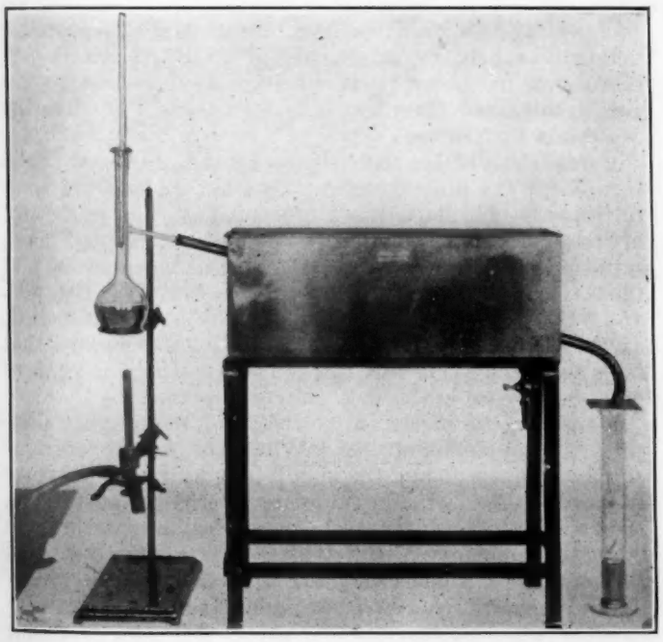


Fig. 1—Apparatus for Making Gasoline Distillation-Test for Government Specification

The Test with This Apparatus Is Simple and Easy To Make but Gives only a Rough Indication of Volatility. It Does Not Necessarily Follow That Two Gasolines, Both Meeting the Volatility Specification, Will Perform Similarly in an Engine so far as Volatility Is Concerned. It Is Hoped To Obtain a Better Interpretation of Results Obtainable from the Conventional Method of Testing with This Equipment

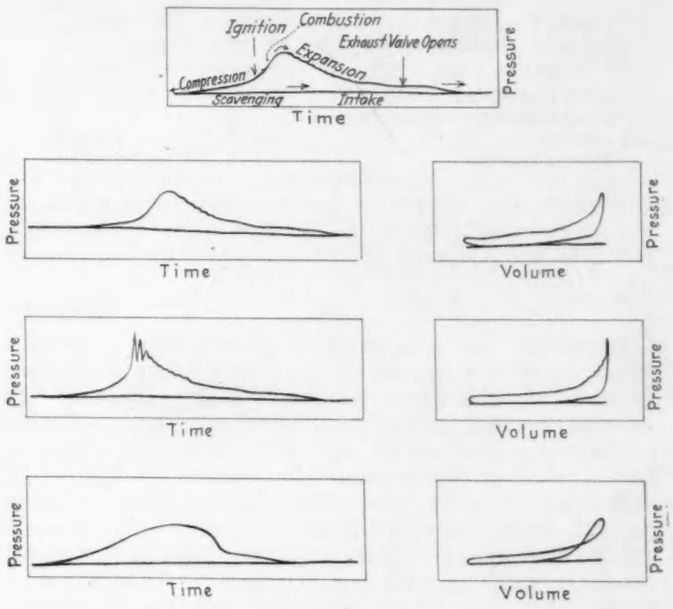


Fig. 2—Typical Indicator Cards of Normal and Abnormal Combustion

The Top Card Shows the Succession of Events in Normal Combustion of the Charge in an Engine. Those Below at the Left Are Pressure-Time Cards and Those at the Right Pressure-Volume Cards. The Top Pair of Indicator Cards Are of Smooth Normal Combustion. The Second Pair from the Bottom Show the Disturbance That Characterizes Detonation, and the Bottom Pair Show the Effect of Preignition on Pressure in the Cylinder

Must Develop Engines and Fuels Together

The question often is asked: How are automobile manufacturers to increase compression until the distribution of suitable fuel is nation-wide? The refiner asks, in turn: Why should we trouble to produce non-detonating fuel until there is a real need for it? The answer, of course, is that the two developments must go together; and a point which is often lost sight of is that the antiknock fuel is of distinct advantage in existing engines. I should like to give just one example, admitting beforehand that it is rather an exceptional case.

In a rather hilly city a large taxicab organization recently made a 30-day trial of two gasolines, both approximating Government specification while differing mainly in their detonating characteristics. Two groups of 25 cabs each were set aside for this test and no carbureter, spark or other adjustments were made. The performance of the individual cabs differed considerably, but the final results appear as presented in Table 1.

These figures show an advantage of 13.81 per cent in consumption with the antiknock fuel. This is undoubt-

TABLE 1—EFFECT OF NON-DETONATING PROPERTIES OF GASOLINE ON TAXICAB OPERATION

Gasoline Used	Ordinary	Antiknock
Total Cab Miles	59,900.1	62,917.5
Total Gasoline Consumption, miles	6,270.5	5,784.5
Miles per Gal.	9.554	10.876

edly more than ordinarily would be noticed in a passenger-car, but it is particularly significant because this test was made during the winter when the amount of idle engine-running was great and traffic conditions were extremely heavy. My excuse for showing these figures is that they are very interesting and bring out some of the points on which I have been commenting. The results are characteristic of those that could be obtained by any similar set of comparisons.

Most detonation tests are made in the laboratory, and I do not think it is realized generally how easy and with what a fair degree of accuracy detonation tests can be made on the road.

THE DISCUSSION

GEORGE G. BROWN[3]:—My experience in testing the antiknock properties of fuel on the road may be of interest in verifying the results reported by Mr. Clayden. As an experiment, I had 3/32 in. planed off of the underside of the engine-head of my car. This converted the engine into a relatively high-compression engine which gave an increase in mileage from about 12½ to about 13 miles per gal. under ordinary driving conditions with the usual run of fuel obtained from gasoline pumps and without special regard to antiknock qualities. This shows, I think, what may be expected from the use of higher-compression engines even if the fuel does not possess sufficient antiknock properties to prevent audible detonation and no change is made in the gear-ratio. With the high-compression head the engine now pulls steadily at wide-open throttle until stalled, without knocking, when using a fuel that corresponds in antiknock value to ethyl gasoline. With ordinary gasoline the engine sometimes knocks rather badly in climbing hills and the gears have to be shifted.

Mr. Clayden made one statement in passing to which I am inclined to take exception. He stated in effect that antiknock value is more important than the volatility of fuel. It is true that antiknock properties will become more important than at present as engines of higher compressions are used, but volatility is now, in my opinion, the most important property of motor fuel. This is particularly the case in cold weather when many drivers change the carbureter adjustment so that their cars will run satisfactorily in intermittent service. If, however, fuel of sufficient volatility can be supplied that will make it unnecessary to change the adjustment, the driver will obtain better mileage. This increase in mileage and improved performance, due to proper volatility, is greater than can be expected from an increase in antiknock value without increased volatility at low temperatures, in the case of present-day engines.

[3] Professor of chemical engineering, University of Michigan, Ann Arbor, Mich.

[4] See THE JOURNAL, April, 1926, p. 393; and August, 1926, p. 156.

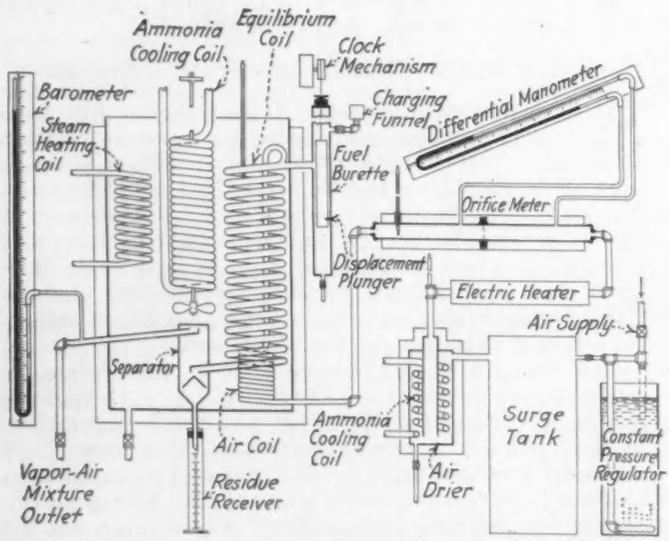


FIG. 3—EQUILIBRIUM-AIR-DISTILLATION APPARATUS FOR DETERMINING GASOLINE VOLATILITY

This Is Similar to the Apparatus Used at the Bureau of Standards but Has a Larger Equilibrium Coil, Shown at the Right in the Chamber, and Is Equipped To Operate at Temperatures of —40 Deg. Fahr. The Principle Involved and Method of Measuring Volatility Are Described in the Text

VOLATILITY IS OF DIFFERENT KINDS

Volatility may be defined as the relative quantity of fuel vaporized under specified conditions. The distillation method of the American Society for Testing Materials for determining volatility, as described by Mr. Clayden, although a standard method, is in many ways unsatisfactory. T. S. Sligh, Jr., of the Bureau of Standards, has described an equilibrium-air distillation[4] in which volatility is determined under conditions closely resembling those in the intake-manifold of an engine. The apparatus in which this determination is made is shown in Fig. 3, illustrating the arrangement of the apparatus as used in the fuel laboratories of the Department of Chemical Engineering at the University of Michigan. It is similar to that described by Mr. Sligh, but has a larger equilibrium coil and is equipped to operate at temperatures of —40 deg. fahr. The principle involved need not be repeated here, but I believe this method of measuring volatility should be given careful consideration in any discussion of motor fuels, as it gives information not readily obtained from the American Society for Testing Materials distillation.

Comparison of the data shown by the curves of Fig. 4 brings out the differences in the A.S.T.M. and the equilibrium-air distillations. Unfortunately, the end-point of the former distillation is popularly accepted as a criterion of the volatility of the fuel. A comparison of the A. S. T. M. end-points of fuels Nos. 13, 102, 104, 108, and 111 with the equilibrium-air-distillation end-points, as shown in the lower part of the chart, indicates that fuels with the same A.S.T.M. end-points may have dew-points differing by 20 deg. fahr. or more.

Moreover, the important volatility of a fuel is the volatility at low temperatures. When the engine is thoroughly warmed up and the manifold is heated to temperatures of 140 to 200 deg. fahr. or more by exhaust gases, the volatility of any product now sold as a motor fuel is more than adequate. But when the engine is cold and the intake-manifold is only slightly warmer than atmospheric temperature, few fuels possess sufficient volatility to form an explosive mixture unless over-rich mixtures are used. When supplying 12 parts of air to 1 of fuel by weight, as was done in these equilibrium-air distillations, about 60 per cent of the fuel must be vaporized to form an explosive mixture. When the throttle is partly closed the reduced pressure increases the volatility of the fuels, and when the mixture is drawn rapidly through the intake-manifold a mist may be distributed

to the cylinders, so that the minimum volatility for operation with a 12-to-1 mixture corresponds to about 40 per cent vaporized on the equilibrium-air distillation instead of 60 per cent.

End-Point an Insufficient Criterion

It is evident from the curves of Fig. 5 that the American Society for Testing Materials end-point is particularly useless as a criterion of effective volatility at low temperatures, as well as inadequate to indicate the dry-point or dew-point when vaporized in an air-stream. This seems to be contrary to the popular belief, which has given an exaggerated importance to the A. S. T. M. end-point. In my opinion the A. S. T. M. end-point is about the least important single point obtained in the A. S. T. M. distillation. In many cases it is actually misleading to judge a fuel by its A. S. T. M. end-point.

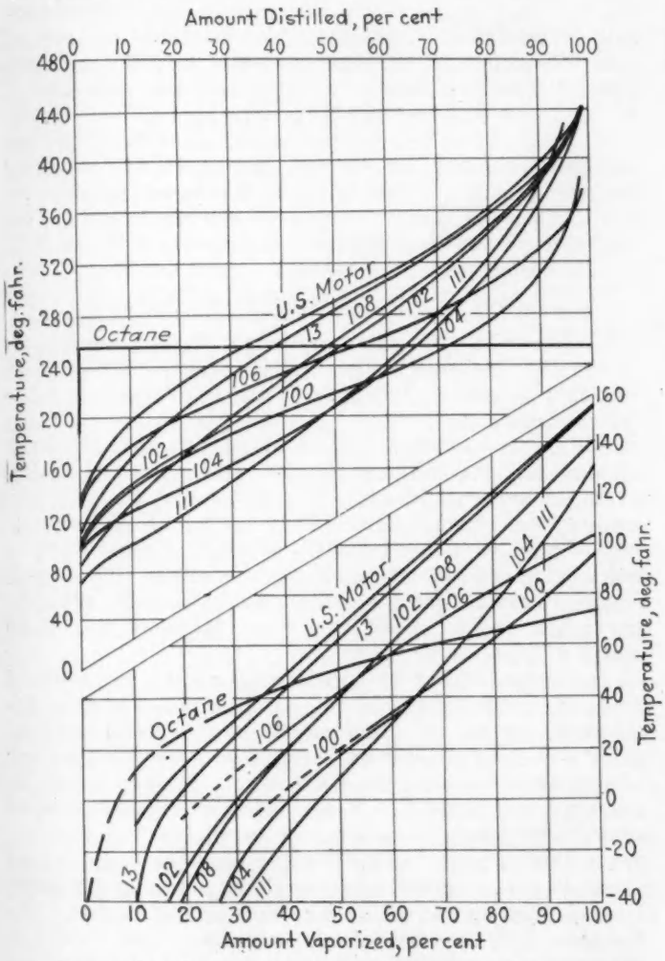


Fig. 4—Distillation Curves of Different Fuels by Two Distillation Methods

Curves in the Upper Portion Are from Distillation by the Method of the American Society for Testing Materials. Those in the Lower Portion Are by the Equilibrium-Air-Distillation Method. Comparison of the End-Points of Fuels Nos. 13, 102, 104, 108, and 111 by the Two Methods Indicates That Fuels with the Same A.S.T.M. End-Points May Have Dew-Points Differing by 20 Deg. Fahr. or More

As manufacturers are fitting cars with highly heated intake-manifolds to obtain reasonably good distribution with fuels of low volatility, it is necessary for best results to use a fuel of sufficiently low volatility at the high temperatures in the manifold when it is warmed up. Fuel No. 100, which is very volatile at a high temperature, causes an actual decrease in engine performance at high temperature, whereas fuels that require a high tem-

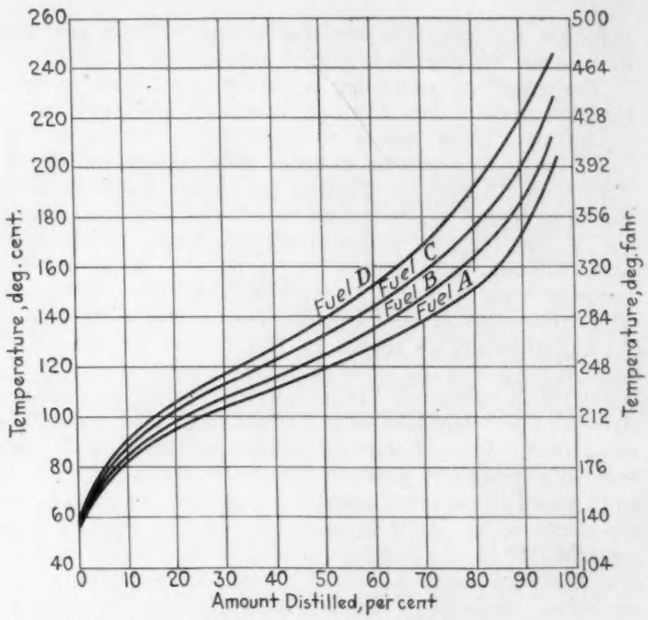


Fig. 5—American Society for Testing Materials Distillation-Curves of Four Fuels

Although the Low-Temperature Volatility of the Fuels Is Substantially the Same, Fuel *B*, with a 420-Deg-Fahr. End-Point, Is More Volatile at High Temperature than Fuel *D*, Which Has an End-Point of 467 Deg. Fahr.

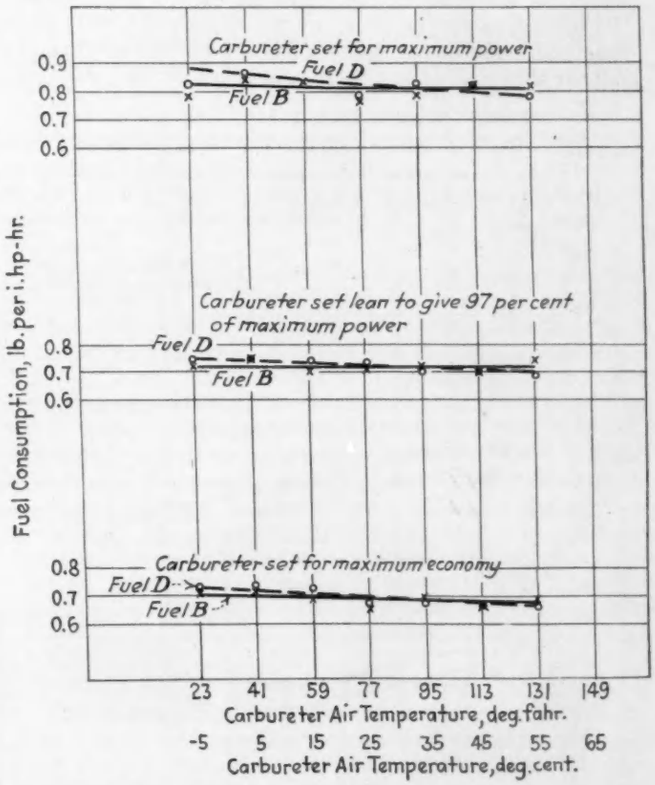

Carbureter set for maximum power
Fuel D
Fuel B
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb. per i.hp-hr.
Carbureter Air Temperature, deg. fahr.
Carbureter Air Temperature, deg. cent.

Fig. 6—Fuel Consumption at 500 R.P.M. and Part Throttle

As the Temperature of the Air Entering the Carbureter Is Increased above 115 Deg. Fahr., the Consumption of Fuel *B*, Which Has the Lower End-Point, Increases, but the Consumption of Fuel *D*, Which Has the Higher End-Point, Continues To Decrease so That at Air or Manifold Temperatures Exceeding about 140 Deg. Fahr. Fuel *D*, with an End-Point of 472 Deg. Fahr., Shows Less Consumption per I.Hp-Hr. than Fuel *B*, with an End-Point of 417 Deg. Fahr. This Fact Is Important as Most Cars Are Driven at Part Throttle Most of the Time and Heat Must Be Supplied to the Manifold for Adequate Acceleration Under These Conditions, unless a Fuel with a High Partial Volatility, Such as No. 111 (Fig. 4), Is Used. Low End-Points Are Not so Important as They Are Assumed To Be with Modern Engines, in Which the Manifold Temperatures Are Usually Well above 140 Deg. Fahr.

perature for complete vaporization give better performance when the engine is highly heated.

The effect of supplying a less volatile fuel at high temperatures is brought out by results obtained in the Cooperative Fuel Research, as reported by Stephen M. Lee[5]. Fig. 5, reproduced from that report, shows the American Society for Testing Materials distillation for the fuels tested. The initial, or low-temperature, volatility of the fuels is substantially the same but fuel B, with 420-deg.-fahr. end-point, is more volatile at high temperatures than fuel D, with 467-deg.-fahr. end-point. The differences at part throttle are evident from Fig. 6. At full throttle, as shown in Fig. 7, no increased fuel-consumption can be noticed as the temperature of the manifold is increased. Inasmuch as most of our cars are driven at part throttle most of the time, these results are important. It is frequently stated that gasoline of high volatility gives less power. The volatility referred to is high volatility at high temperatures, and the reason for the decrease in power is probably that the fuel becomes superheated in the engine manifold and cylinder and the hot mixture causes a loss of power, whereas fuels that vaporize completely at higher temperatures give full engine-power.

Constant Volatility at Different Temperatures Best

So long as the operating temperature of the manifold varies over wide ranges, different fuels should, theoretically, be supplied to the different cars depending upon the operating temperature of the manifold. This is impractical. Motor-car manufacturers ask for uniform fuel so that they can design their product to fit the fuel. It is equally pertinent that refiners should request uniform motor-cars.

As it is impossible and undesirable to supply different fuels to different automobile engines to meet the different temperature-conditions, a compromise of some sort should be reached. A fuel of practically constant volatility under all temperature conditions existing in the intake-manifolds and carbureters would be ideal from this consideration. Such a fuel would more nearly approximate a vertical line on the equilibrium-air distillation, such as fuel No. 111, and have a low front and high end on the A. S. T. M. distillation.

An end-point of 450 deg. fahr. on the A. S. T. M. distillation may be perfectly satisfactory even when gasoline is produced by efficient fractionation. If fuel of this end-point can be used generally it will enable the refiner to make a deeper cut into the crude, and the fuel so produced will be entirely satisfactory if it has sufficient volatility at low temperatures. Sufficient low-temperature volatility can be obtained readily by blending natural gasoline. This problem becomes largely economic once the public learns to discriminate between the effective low-temperature volatility and the A. S. T. M. end-points, which have nothing in common.

[5] See THE JOURNAL, July, 1923, p. 3.

[6] Supervisor of process division, Atlantic Refining Co., Philadelphia.

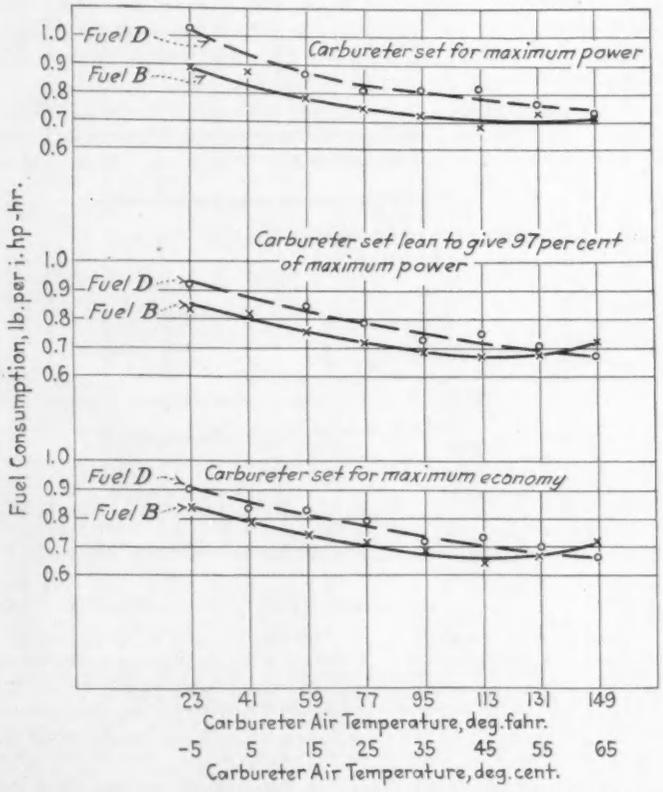

Fuel D
Fuel B
Carbureter set for maximum power
Carbureter set lean to give 97 per cent of maximum power
Carbureter set for maximum economy
Fuel Consumption, lb. per i.hp.-hr.
1.0
0.9
0.8
0.7
0.6
23 41 59 77 95 113 131 149
Carbureter Air Temperature, deg. fahr.
-5 5 15 25 35 45 55 65
Carbureter Air Temperature, deg. cent.

FIG. 7—CONSUMPTION OF FUELS *B* AND *D* AT FULL THROTTLE AT AN ENGINE-SPEED OF 500 R.P.M.
No Increased Consumption Is Shown as the Temperature of the Intake-Manifold Is Increased, Although Heat Is Not so Necessary for Good Performance at Full Load

Gasoline a Relatively Cheap Product

T. G. DELBRIDGE[6]:—I want to talk about three phases of the gasoline topic. The first is of considerable interest; that is, price. In October, 1926, a survey was made which showed that, compared with what $1.00 would purchase in 1913, it would take $1.50 to purchase the same amount of the average commodity in October, 1926. But averages are misleading. As I remember, the top commodity was shoes; they were about 84 or 85 per cent higher than in 1913; that is, you had to spend $1.85 to get what was $1.00 worth of goods in 1913. The bottom commodity was gasoline; that was about 25 per cent over; you had to spend only $1.24 for what was $1.00 worth of gasoline in 1913.

The second thing is quantity. In 1916 we obtained from the crude almost all the gasoline that could be distilled out of it. In other words, crude petroleum contains a certain amount of gasoline and we were getting almost all of that out by distillation. In 1916 we began cracking, and by 1921, a 5-year interval, we had installed some rather clumsy cracking-equipment, viewed from today's development, but we had reached the point where about 48 gal. of gasoline was made by cracking for every 100 gal. that we got out of the crude by distillation. For the year 1926, for every gallon of gasoline that existed in the crude as such and was taken out by distillation, we got out exactly 1 gal. more by cracking the high-end-point constituents, such as lubricating-oil and gas oil. With that work going on with all the refineries of the Country, it seems to me there is no need for anyone to fear that we shall run out of gasoline in our lifetime.

I am asked frequently: Why do we not use benzol as a motor fuel? Mr. Clayden showed some evidence that benzol blends are good fuel. I wish we had enough benzol to go around, but certainly the men in the automotive industry would dislike very much to have 96 or 97 per cent of the automobiles of the Country stop running. That would happen if we had to depend upon benzol for fuel.

Volatility Preferable to Antiknock Quality

So far as quality goes, I think Mr. Clayden may have left an impression that I do not believe is entirely right; that is, as to the importance of detonation. I believe

that detonation will increase in importance, but I do not believe it is today the most important thing about gasoline. I am much inclined to agree with what I think is Dr. Brown's position, that if we must choose between volatility and detonation, I would rather try to get the volatility just right for a given engine and take a chance on detonation. I say that with some reluctance, as I do not feel really qualified to express that as a firm opinion. There is a reasonable doubt as to the relative importance of these two points. I think detonation will have to be provided against. If it is, it will be done through cooperative work largely among the colleges and universities, the Bureau of Standards, the Society, and oil refiners.

One point that I want to emphasize is that gravity has absolutely nothing to do with the quality of gasoline.

CHAIRMAN W. R. GORDON[7]:—Do you think there is any danger in using benzol due to sulphur in the commercial product?

MR. DELBRIDGE:—Benzol put out by the reputable firms 5 or 6 years ago contained about 0.22 per cent of sulphur, which did no harm, because, if the benzol was blended with gasoline in the usual proportion of 40 per cent benzol and 60 per cent gasoline, the sulphur content would drop down so that it would not be at all dangerous.

Benzol that was not properly refined has been put out in some localities, particularly in the Southern States. I think the sulphur content ran as high as 1 per cent or a little more. There is real danger with a fuel like that, particularly in cold weather when there is more or less condensation of water in the crankcase. Combustion produces sulphur dioxide, which is then oxidized, forming the trioxide that in turn combines with the water in the crankcase to form sulphuric acid and constitutes a great menace from corrosion. However, benzol blends that are put out by reputable companies would not contain sufficient sulphur to be dangerous, so far as I know.

No Danger from Sulphur in Gasoline

CHAIRMAN GORDON:—What is the danger from sulphur in commercial gasoline? We have taken drippings from the tail pipe of the car with the engine idling and by tests have found sulphuric acid present.

MR. DELBRIDGE:—Gasoline that meets the present specifications has not more than 0.1 per cent of sulphur. That figure probably is lower than it actually needs to be, but in drawing up specifications for the Federal Government it is necessary to be safe. I do not believe that there is any danger from sulphur in any of the gasoline of today except possibly at extremely low temperature or in cars in which considerable water is permitted to get into the crankcase. So far as I remember, very few gasolines are now sold that contain more than 0.10 per cent of sulphur; I should say the average is only 0.07 or 0.08 per cent, taking the Country as a whole.

CHAIRMAN GORDON:—How is the layman to distinguish between good gasoline and poor gasoline? If we could have some marks by which we could buy our gasoline, it would help.

A. LUDLOW CLAYDEN:—He cannot do so except by the somewhat clumsy method of trial and estimation. We cannot distinguish between gasolines very well by specifications, and when the specification is lacking or is not understood, the situation is worse; all one can do is to try the fuel. But the average man has this protection, that never in the history of the oil industry were refiners trying so hard as they are today to produce the best possible fuel.

I was very glad that Dr. Brown described the equilibrium-air method of testing for volatility. I agree with him and Dr. Delbridge that perhaps I did suggest in my paper that volatility is of less importance than it really is. It is, of course, of extreme importance, and, like Dr. Delbridge, if it were necessary to choose between volatility and antiknock quality, I too should give considerable attention to the volatility.

Generally, throughout the Eastern seaboard, the antiknock quality of most of the gasoline is distinctly superior to that of gasoline in the West and Middle West, and it is still better in California, where the average antiknock quality of gasoline is the highest for any section of the Country.

Next Move Up to Car Builder

The automobile builder, I think, must make the next few moves. This question of more accurate heat-control, and heat control at the right point, can be studied rather quickly and thoroughly, and I think good results can be obtained. It is worthwhile, I believe, to leave off a little nickel-plating and put a little more mechanism under the hood to reduce the gasoline bill. More intensive work can be done on combustion-chamber design than has been done. Many persons seem to assume that since Ricardo produced his voluminous works on the subject, everything pertaining to this question has been settled, but I do not think that Ricardo did more than write an elaborate preface; most of the work remains to be done. We are ignorant of many facts about materials from which engines should be constructed. Unquestionably the detonating tendency of an engine is much less with aluminum pistons than with iron pistons. The tendency is also reduced by the use of an aluminum cylinder-head instead of an iron cylinder-head, but to what extent no one knows.

Certainly much remains to be done on a detailed study of temperatures in engines. Detonation occurs readily in a great many engines simply because some particular spot in them becomes very hot. In one car that is manufactured in large numbers the temperature of some spots in each cylinder-head would run up to about 450 deg. fahr. when the outlet-water temperature was only 160 deg. fahr., and detonation would occur readily, but slight changes in the internal design of the cylinder-head made a great difference in this respect. That is the kind of thing that the automotive engineer can study usefully, and I believe he is doing so in the majority of cases.

P. B. JACKSON[8]:—It would be interesting to have Mr. Clayden tell about the detonating characteristics of different fuels in the same engine. In certain T-head engines having a compression-ratio of 4¼ to 1, you can get severe detonation at wide-open throttle conditions at speeds of 500 r.p.m. and less with the best fuel obtainable. Then, with another engine and using a very poor fuel, you can actually have compression-ratios of more than 5 to 1, without detonation. It seems to me, contrary to Mr. Clayden's paper, that it would be easier to change the engine than to change the fuel all over the Country. When I asked Mr. Clayden how the companies that exhibited cars in the New York City automobile show with compression-ratios of more than 5¼ to 1 will meet the situation, he told me the engines will operate all right in the East but not in the West. That is a serious matter.

MR. CLAYDEN:—Mr. Jackson's question really amounts

[7] M.S.A.E.—Transportation engineer, Pierce-Arrow Motor Car Co., Buffalo.

[8] M.S.A.E.—Assistant engineer, Pierce-Arrow Motor Car Co., Buffalo.

to this: Will a series of gasolines of different antiknock qualities perform differently in engines of widely different design? Or, put another way, would we have to grade the gasoline on the detonating characteristics of one engine and grade them the same on detonating characteristics of another engine?

If we were to use an average commercial gasoline in an engine having a combustion-chamber of the worst conceivable design, we should have to keep the compression-ratio down to not much more than 4 to 1; whereas, if the same gasoline were used in an engine having a combustion-chamber of the best conceivable design, we could not raise the compression-ratio much above 5 to 1.

Variable Heat Control of Manifold

R. S. Ellis[9]:—What is the opinion of the speakers regarding heat control of the manifold with relation to the various kinds of gasoline and the effect that could be produced by such control on detonation and the volatility of the charge as it enters the cylinder?

Mr. Brown:—Heating the manifold is inadvisable from some standpoints but is necessary from others. It increases the tendency of the fuel to knock, but is particularly necessary when operating at light loads with our present motor fuels; therefore heat should be applied in varying amounts depending upon the load on the engine and the temperature. If the heat is controlled in this way, the manifold is heated when necessary but not enough to increase noticeably the tendency of the engine to knock when laboring at open throttle.

Question:—When speaking of heat in the manifolds, did you refer to all types or to a specific type of manifold that was tried?

Mr. Brown:—Tests we have made with heated manifolds indicate that, so far as knocking is concerned, it makes little difference whether we heat the air or heat the manifold right up above the carbureter or somewhere else; the general effect is very much the same, depending upon the actual temperature to which the mixture is heated.

Mr. Clayden:—Most people cannot or do not adjust a carbureter for cold-weather conditions so that it supplies a somewhat richer mixture that enables them to start the engine more easily. This function could easily be taken care of by a thermostat at a cost of $1.00 or $1.25 per car. I do not think the automobile manufacturer considers it worth $1.25 to help the user save 10 per cent of his fuel in cold weather. The proportion of heat in the manifold never has been worked out properly. It can be regulated to a considerable extent by thermostatic control.

Donald S. Cox[10]:—What are the relative merits of the different fuels as regards carbon deposition, especially those having the higher end-points? Do you get greater carbon-content with the higher-end-point fuels than with the lower-end-point fuels?

Mr. Clayden:—As combustion in the engine is perfected, the tendency to deposit carbon will decrease. We have a generalization that the higher end-point fuel tends to deposit more carbon, but I should say that you never would get any experimental evidence within the range of commercial gasoline to support that theory. To be sure, when detonation occurs in an engine the formation of carbon deposits is very rapid; a tremendous quantity of soot is released during the period of detonation.

Question:—What is the relation of the present standard gasoline to fuels Nos. 111 or 13, if any relation exists? And was the fuel Dr. Brown used a specially volatile fuel or one of the commercial products that we buy today?

Mr. Brown:—The fuel marked U. S. Motor was gasoline of United States motor-fuel specifications. Most of the gasoline now sold as motor fuel is more volatile at low temperatures than the Federal specification limits. Fuel No. 13 represents one of the fuels now widely sold as United States motor gasoline. Fuel No. 111 is about the most volatile fuel that can be used to advantage. It was prepared by blending equal parts of natural gasoline and fuel No. 13.

Question:—What is the difference between preignition and detonation?

Mr. Brown:—Preignition is the term applied to self-ignition of the fuel upon compression independent of the spark. When a large amount of carbon accumulates in the cylinder and the engine is driven hard, the carbon becomes highly heated and ignites the charge upon compression. Detonation occurs only after the charge has been ignited by the spark. It is entirely different. Detonation, although influenced by some of the same factors that induce preignition, heats the cylinder so that preignition will usually follow any extended period of detonation, but the two must not be confused.

Relation of End-Point to Oil Dilution

Question:—Have any experiments been made to determine the percentage of crankcase-oil dilution, say on gasoline with 390 or 400 end-point as against gasoline with 437 or 450 end-point; also, do natural gasolines produced in the Eastern fields and those produced in the Western or Southwestern fields differ in antiknock qualities?

Mr. Brown:—Everything else being equal, the higher the end-point is, the higher the crankcase-oil dilution becomes. On the equilibrium-air distillation fuel No. 111 was completely vaporized at a lower temperature than fuel No. 13. Therefore the end-point alone on the American Society for Testing Materials distillation is not adequate to explain crankcase-oil dilution. My personal opinion is that crankcase-oil dilution has been overemphasized, possibly as an effective alibi by repairmen. I think more trouble arises from dirt in the oil than from dilution, and that modern engines are constructed to eliminate excessive dilution in the crankcase, unless improperly driven with too rich mixtures.

So far as I have been able to determine, the compounds present in natural gasoline from the Eastern and Mid-Continent fields are very much the same. Likewise, there is no noticeable difference in antiknock properties of natural gasolines of about the same volatility from these fields. This is to be expected, as the antiknock value depends upon the relative amount of the different compounds present.

Ethyl Gasoline Not Injurious to Metal

A Member:—My garage man tells me that tetraethyl lead gasoline is not entirely satisfactory, as there is some danger of the scoring of the cylinders. If there is any such danger I think it should not be used.

Mr. Clayden:—The statement that ethyl gasoline has any reaction on the metals of the engine is ridiculous. It could not possibly have any reaction. In engines that have been run on very rich mixtures of ethyl gasoline

[9] A.S.A.E.—Superintendent of branches, Foss-Hughes Co., Philadelphia.

[10] M.S.A.E.—Research engineer, Pierce-Arrow Motor Car Co., Buffalo.

a small quantity of the chemical can be found in the carbon deposit.

Someone has asked how much tetraethyl should be used. It depends a great deal on the design of the engine and the purpose for which the engine is used. I believe that the compound is regularly used up to about 10 cc. (0.61 cu. in.) per gal. Do you know, Dr. Delbridge?

DR. DELBRIDGE:—No, but the Surgeon General says that 1 part in 1200 is all that should be used, and that is the proportion to which the ethyl-gasoline corporations are limited.

MR. CLAYDEN:—It may be of interest to know that the Ethyl Gasoline Corporation has what it calls a standard of quality as regards antiknock, and the quantity of tetraethyl that must be put into gasoline to bring it to that standard varies with the gasoline anywhere from virtually none to between 4 and 5 cc. (0.244 to 0.305 cu. in.) of ethyl fluid per gal. So that between nil and 3.5 cc. (0.214 cu. in.) of tetraethyl lead is about the range for ordinary commercial gasoline.

The aromatics that have so far been examined are practically all good antiknock materials. The proportion of such aromatics in commercial gasolines is very slight, and it is questionable whether the antiknock property of some gasoline that is fairly rich in aromatics is due to aromatics or to other substances. It was assumed conventionally that the paraffin-chain series of compounds were bad detonators and as the benzine-ring formation was more closely approached the non-detonating property improved; but recent research-work has thrown considerable doubt upon that. When it is found that the detonating property of gasoline is decreased by producing the gasoline from the crude by cracking instead of by straight distillation, we can say we increase the presence of aromatics, but there are so many different kinds of constituents in the crude oil that the improvement in quality cannot be attributed definitely to any one of them. The Ethyl Gasoline Corporation has recently isolated some new pure hydrocarbons which work entirely differently from what was expected. The material, which was expected to be an extremely likely "knocker," is one of the best antiknock materials discovered. Practically we do not know much about the subject.

QUESTION:—What effect does detonation have compared with the end-point of the gasoline?

MR. BROWN:—In general, the compounds that come over to the upper end of the American Society for Testing Materials distillation have a greater tendency to detonate than the low-boiling compounds. With everything else being equal, we should expect that higher end-points would mean greater knocking tendency; but this tendency is far more accurately indicated by the 50-per cent point than the end-point, so that end-point in itself is just as misleading regarding antiknock quality as it is regarding volatility.

QUESTION:—In driving, when a detonation starts, if the spark is retarded the detonation stops. Does that reduce the engine power?

MR. CLAYDEN:—Retarding the spark to eliminate detonation is accompanied immediately by a loss of power. For any given engine-speed an ideal degree of spark-advance is available which the automatic spark-devices now generally employed are intended to provide. None of these is perfect; some are fairly good. If you assume a non-detonating fuel, you will get the minimum of detonation in the engine with the spark advanced; therefore, further elimination of detonation by retarding the spark does necessarily mean loss of power.

GASOLINE-POWER REVOLUTIONIZED WAR

IN the history of war, if not today, it will be realized that the introduction of gasoline-power marks a change as all-embracing as the introduction of gunpowder. Gunpowder changed the form of war but not its primary tactical function. Before firearms were used battles were mainly assaults; after they were adopted they became attacks culminating in assaults. Armies advanced by roads, then deployed, frequently when in view of each other, then attacked over 200 to 300 paces of ground, and finally delivered an assault. In both cases mobility was developed from protected offensive power.

By the beginning of the present century, the range and accuracy as well as the volume of fire of weapons had increased to such an extent that the assault became the exception and not the rule. This was well recognized after the Franco-Prussian and Russo-Japanese wars, with the result that tacticians saw that frontal attacks had become unprofitable. Therefore they advocated what is known as enveloping attacks.

In the great war fire-power had largely been increased by the general adoption of the machine-gun, and such vast numbers of soldiers were deployed that more frequently than not fronts became continuous and, until they were broken, enveloping attacks were rendered impossible. The question of how to break the enemy's front had, therefore, to be answered before mobility could be regained. It is here that gasoline-power came to our assistance.

Without gasoline-power the great artillery battles would have been impossible, since the millions of shells fired could not have been carried forward from the rail-haeds. Without it, armored-car and tank attacks would have been unknown. The object of battle will remain the attainment of economical victory through mobile protected offensive-power. —Col. J. F. C. Fuller, British Army, in *Infantry Journal.*

PETROLEUM AND NATURAL-GAS RESEARCH

THE field of petroleum and natural gas bristles with research problems. Many of these are of a chemical engineering sort and have to do with the general introduction of better fractionating equipment, the conservation of heat, the minimizing of corrosion in cracking equipment, and so on. Many others are of a more strictly chemical nature, such as the direct production of anti-knock gasoline, the removal of sulphur or the derivation from waste gases of alcohols, glycols, solvent acetates, and a wide range of other valuable compounds. A million gallons per day of propane and butane, chiefly from casing-head gasoline plants, is awaiting profitable utilization as raw materials for chemical industry.—From an address by Arthur D. Little.

Modern Automobile-Production Methods

By W. K. Swigert

Indiana Section Paper

MODERN production methods are discussed in contrast with methods of 20 years ago. The author asserts that the greatest development in recent years has been the establishment of a production-planning department and that it is as essential to engineer the production department as to engineer the car. Next to the development of improved and labor-saving machinery, the principal development in production methods has been the planning of plants and equipment so that material will flow directly and steadily from the receiving and stock rooms to the shipping department, thereby avoiding waste of time and non-productive labor in handling parts between operations.

Reconstruction of buildings and relocation of operations are discussed, and this work is declared to be fully as scientific as work in the chemical laboratory. Conveyor systems and progressive operations on the chassis result in faster and cheaper production and reduce confusion.

The use of single-purpose machines means larger investments but the saving in labor quickly repays the extra investment.

The development of multi-purpose machines capable of adjustment to perform differing types of work has been a blessing to small factories.

Inspection of raw materials and materials in process has reached a high degree of development and has been an important factor in the industry. Gages, templets and precision inspection-tools are supplied to the inspection department, and the inspectors are the policemen who hold the workmen to careful and accurate work.

OUR conception of modern automobile-production methods and any discussion about these methods must, of necessity, include a consideration of production methods of the past. Not only is it necessary to establish the contrast between past and present methods in automobile production if we are to consider the subject wisely, but there should be an understanding of the reasons for the changes that have brought about present methods. Evidently some methods of past years were at fault or we should still be following all of them. We must know why past methods were wrong and why present methods have been adopted to correct the earlier faults. Knowledge of the history of any movement is necessary if we are to have a full understanding and appreciation of the results of that movement.

The greatest development in automobile production, I believe, has been the establishment of a production-planning department, at the head of which must be a thoroughly practical man to approve various methods before they are adopted, with the view of increasing production by the application of special equipment where found necessary but with the least expenditure for additional equipment. It is just as essential to engineer the production and manufacturing departments as it is to engineer the car itself, for without thoughtful consideration toward economical manufacture the best design of car will prove a failure, no matter how well engineered. However, it does not follow that new methods, new short-cuts and new equipment will not constantly be adopted to decrease manufacturing costs.

The function of a production-planning department should be that of planning buildings and machine-shops, routing of materials, assembly, inspection, and commercial and special tooling.

Machine-shop and assembling practices differ in the mass-production and small-production plants. Obviously, the procedure in the Ford, Chevrolet or Dodge plants must be different from that in the Marmon, Stutz, Lincoln, or Packard plants. Conveyor systems can be put to much more extensive use in the mass-production plant, where time cannot be taken to give an individual adjustment that may be advisable, than in the small-production plant. Stopping one unit on the conveyor line may mean upsetting the entire line or the day's production. However, as there are more small-production plants than mass-production plants, and as most of us are interested in the former type, I shall devote most attention to the advancement of methods in the smaller plant.

Contrast of Old with New Methods

With the exception of improved and labor-saving machinery, the principal development in production methods has come through the efforts to have material flow smoothly in a continuous line from the receiving and stock rooms to the shipping room, without skipping here and there throughout the plant. Labor is now the most costly item in production, and the more direct the flow of material is, the greater is the saving in non-productive labor and in time, which is also a much more important factor than it was a decade ago.

Formerly we carried the work to the machines. Now we take the machines to the work. Twenty years ago, when a plant was laid out, it was the first convenience, and not the ultimate convenience, that determined the location of the operations and the machines. A particularly cumbersome machine was placed near the door through which it was brought into the plant, because it was difficult to move. Some other machine was placed in a corner for another equally foolish reason. The last machines to be placed had to occupy the remaining vacant spaces, even though they might be almost inaccessible. As a result of this layout, it probably was necessary to carry a piece of material to every corner of the shop for the performance of four successive operations on it. The waste of time and labor was tremendous, but time and labor were comparatively cheap and it was not thought necessary to conserve them.

Similarly, plants were constructed without specific

[1] M.S.A.E.—Production manager, Stutz Motor Car Co. of America, Inc., Indianapolis.

regard to their later utility, or to their adaptability to manufacturing operations other than those for which they were to be used first. If it was planned to use a certain building for the enameling department, that building was constructed so that it could never be used advantageously for anything else, although it was possible that the company might later be compelled to move the enameling department to another location or to abolish it altogether. Neither were the buildings planned with a view to having operations follow in sequence. The machine-shop was usually on the ground floor, but the polishing room might be in the farthest corner of an upper floor of another building, because that corner was otherwise unoccupied and the polishing department would fit in there.

This former disregard for the general utility of buildings has worked a serious hardship during these later years when progress has demanded that the material flow in a continuous line from the receiving room to the shipping department. When plants are built now they are designed to meet, not only present but also future, requirements. However, very few plants are being built; in fact, almost none for new enterprises, so it brings us back to the fact that it is obligatory that we make over the plants that were built for antiquated production-methods.

Even alteration of the buildings will not always accomplish the desired results. For example, three or four factors may combine to compel the production department to leave a certain department in its original location, although its removal to another location might be desirable in the new factory-layout. Any one of these factors, such as the lighting problem, might be overcome, but to overcome the combination of three or four factors may be too difficult. Even so, manufacturers have revamped their buildings and relocated their various operations so that there is the least possible interruption or loss of energy in moving the material from the first to the last stages of production. At the Stutz plant, for example, the cylinder-block moves steadily from the normalizing oven to the cleaning, milling, boring, and other operations until it reaches the assembly line. Each of the other units or sub-assemblies moves in a steady procession down its particular channel until it reaches the engine-assembly line at the point where it is needed, and at the time when it is needed. The assembly line is not clogged with two truck-loads of connecting-rods brought in just because they were ready for use. The flow of connecting-rods is regulated, through proper planning, to correspond with the movement down the assembly line, so that only a sufficient number of rods are available for the engines going through.

Planning the equipment to be used and its location to make the material flow steadily was achieved only after much really scientific study. This work is fully as scientific as that in the chemical laboratory, and it should never be delegated to any person not thoroughly qualified for it. The progressive movement of material reaches its highest development in the mass-production plants, where almost everything is carried by mechanical conveyors, but even in the smaller plants, where conditions make such extensive use of mechanical conveyors impractical and actually unnecessary, the problem should be handled by an expert.

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The Change in Machine-Shop Methods

To return for a moment to consideration of machine-shop practice, a comparison of machine-shop methods of 20 years ago with those of today brings to mind again the assertion that this is a mechanical age, as now about all the workman has to do is to put the material in the machine and turn a switch or push a shifter. In the old days, the workman was an all-round mechanic, very probably a journeyman who wandered from one place to another and who had to be skilled as an operator of a lathe, a milling-machine, a drilling-machine, a planing-machine, and all other machines, and as a bench hand, if he were to get a job, as no grinding-machines, internal or external, were in use.

The human element entered very largely into all machine-shop work, and, although men were skilled mechanics, it was inevitable that much of the work was not exact. This must always be true when the results depend to any extent on the ever uncertain human element. It was more true 20 years ago than now because the workmen had to have a knowledge of all kinds of machine operations and could not specialize on one. Nowadays an apprentice is a rare person. We simply employ a man, an experienced man if possible, show him how to start and stop the machine he is to use, and put him to work, thereby making him a specialist.

Machines that formerly were hand-operated were later made semi-automatic and then fully automatic. The single-purpose machine of today does not require the highly qualified operator who was needed when the human element played a larger part. When the adjustments and set-ups have been made properly, the man's chief task is to feed material to the machine and remove it when the operation is finished; and, when several minutes are occupied by a machine in performing the operation, the workman is free in the interim to be feeding other machines and removing the finished work from them. Thus, one or two men often can operate four, five or six machines, with a great saving in labor cost over the methods that were in vogue a score of years ago or less.

Naturally, the use of single-purpose machines means the addition of many machines to the shop equipment, with the attending larger investments, but the saving in labor more than repays the machinery investment. There is also a great saving in material, for the uni-

formity and greater accuracy of machine operation reduces the spoilage of material by hand operation.

Multi-Purpose Machine Is a Boon

An advancement that has been a blessing especially to the smaller factory is the development of machines capable of adjustment to take care of differing types of work, should it be necessary to change the character of some operations. Much of the present-day machine equipment is flexible enough to permit a variety of set-ups. For example, standard milling-machines can be converted to a number of special uses that would otherwise require machines of special design and construction, the cost of which would be prohibitive. In the same way, many special machine-tools designed for combination work reduce the shop inventory.

While many shop-operations have not been changed substantially in character, new methods have been adopted in other cases to bring about a great improvement. The lapping of cylinders is a notable example of this. Previously the cylinders were merely ground, leaving the buyer of the car to lap the cylinders when he drove the car on the road. The lapping process now employed not only gives the same result that from 3000 to 5000 miles of driving gives, but it does the work much more quickly and accurately than the grinding could be done under the old methods; in fact, a workman can lap eight cylinder-bores in about one-fifth the time required to grind the same number.

Conveyor Systems Aid Line-Assembly

This devising and planning of methods is not confined to the machine-shop and engine-assembly departments; it applies equally to every phase of work in the production department. Operations on the chassis must be progressive, and the engine must join the chassis line at a given point. Likewise, from another part of the plant, the body moves forward steadily through the paint, trim and hardware departments and on until it meets the chassis at the proper station. So the assembly proceeds until the car is complete.

Assembly work always will consist more or less of hand operations, although most of the development in this phase of production has come with the introduction of the various conveyor systems, which deliver material faster, cheaper and with less confusion to the various points along the assembly-line proper than formerly was possible with man-power delivery of material. It is more than probable that almost all future advancement in car-assembly methods will depend on new and improved conveyor-systems. Mechanical methods have not been devised to make the adjustments that are required in assembly.

Once the completed car is off the production line, there still remains the testing. In recent years mechanical substitutes have been designed and put into practical use to replace the road test. With their eccentric-roller equipment these will test spring action and the strength of the parts probably as well as will the road test, but I believe the latter is essential for checking steering and quietness of operation.

Great Progress Made in Inspection Methods

Detailed inspection of raw materials upon receipt and of materials in process has proved an important factor in all automobile plants, and I believe a much higher standard of inspection has been developed than was ever conceived in the early days of automobile manufacturing. For instance, in the metal trades, previous to the inception of the automobile, the lack of proper machine-tool equipment and measuring tools made the foreman or superintendent responsible for the accuracy of the output of his department. In the early days of the old Cadillac plant, under Henry M. Leland, there were no detail inspectors except in the final car-inspection.

In the old machine-tool days the shop superintendent held the key to everything pertaining to the building of a particular machine-tool. He seemed to carry all dimensions and details of every operation in his mind. The workmen had no blueprints; in fact, there was only one set of blueprints in the plant, which were locked up under the superintendent's supervision, and should the workmen forget a detail, or be unable to duplicate a sample, he was obliged to ask the superintendent concerning the measurements, and if the latter could not give the information from memory, he would slip away to the cabinet of blueprints, exclude all others from the room and secure the elusive bit of information. We worked by samples, templets, ring-gages, or caliper fit, full or scant.

Each workman was held personally responsible to the foreman for the accuracy of his work, and the parts not properly machined the first time were returned to the workman for correction, mostly by hand operations. I recall a picturesque journeyman mechanic of the old school who worked with me many years ago and who did good work, although he seemed to give no particular care to it. One day I pointed to a piece he had just finished and asked, "Rube, how do you know that piece is all right?" "Why, I put me 'mike' on it, didn't I?" he replied.

He had put his "mike" on it, and that was sufficient, whether or not he read his "mike." He made the gesture and that was the only inspection that piece was to get. If it later proved defective when it reached the assembly line, it would go back to Rube for correction.

Certainly great progress has been made in inspection. Duplicate gages, templets and precision inspection-tools of all descriptions are supplied to the inspection department, usually through the production-planning department, to check accurately the duplication of parts. Formerly, dimensions were specified in common fractions; now in decimals in ten-thousandths of an inch.

Foremen are still responsible for the output of their departments but the inspectors are the policemen who cause the workmen to do more careful and accurate work, who keep defective parts from the assembly line, or defective finished products from the owner's hands, thus saving thousands of dollars in money, and more than that value in "grief."

Design Engineer Cooperates with Production Man

Much credit should be given the designing engineer of today who cooperates with the production man to avoid designing parts that are impossible to machine or so intricate as to require special machine-tools and fixtures for their manufacture. Engineers have many times in the past created new designs which made necessary the purchase of complete new equipment.

I was greatly interested in the following statement about American automotive production made recently by Major H. O. D. Seagrave, the famous British engineer and racing driver:

> Americans have forgotten more than England and Europe will ever learn about motoring. Your mass production and its attendant precision is amazing. Of course, we have better theoretical methods and better engineering practice, but then we make cars so well we can't use them.

Head-Lamp Adjusting Mechanisms and Law Enforcement

By WALTER W. MATTHEWS[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

DOUBLE-FILAMENT incandescent lamps and head-lamps as now designed, constructed, and distributed have not sufficiently justified themselves to the public or to the law-enforcement authorities, according to the author, to warrant their use without some restrictions to assure their performance in accordance with the claims made for them.

Insensitive head-lamps are not yet a reality, he asserts, nor can they become so until head-lamp manufacturers give more consideration to the motorist and less to the purchasing agent of the motor-car company.

Adjustment instructions are not made any more difficult because of the vertical-adjusting mechanism, and its use as a means for aiming the beam is justifiable, he holds, especially in the light of recent developments, which indicate the passing of the S.A.E. Standard mounting. Therefore, future development and incentive have not been retarded.

The requirement of two adjustments on this type of head-lamp is not inconsistent nor unjust, it is claimed, in view of the research data compiled by its proponents and of the very evident indecision and disagreement among engineering authorities and its opponents.

Neither of the two chief arguments advanced by the opponents of double adjustment is valid, it is declared, either from a practical or a technical viewpoint. Safety on the highways cannot be subordinated to price considerations, and the question of educating the motorist to the use of his equipment can well be left with the enforcement authorities.

Discussers controvert statements made by the author, assert that the Eastern Conference of Motor-Vehicle Administrators has rescinded the requirement for double-focusing head-lamps and state that quotations presented in the paper to support the contention for this type of equipment are fragmentary and misleading and were made with full knowledge of the real opinion of those quoted on the subject. Data are given of inspections in Massachusetts in May, 1927, which show that more double-adjustment head-lamps than single-adjustment head-lamps were not properly focused and that the double-adjustment head-lamps showed more than twice as much variation of tilt between upper and lower beams as the single-adjustment head-lamps.

Demonstrations made with both types indicated the serious difficulty of adjusting the double-focusing type and relative ease of focusing the single-focusing type and also that results obtained from inaccurate two-filament lamps were about the same in the two types of head-lamp.

One discusser suggested and described a method of overcoming the difficulty by building a non-focusing head-lamp having an adapter ring similar to the ring used for assembling the lamp base and the glass bulb, which will provide a seat for the lamp and correct the inaccuracies of base placement in manufacture.

All discussers were given opportunity to revise the stenographic report of their remarks at the meeting before publication and to submit supplemental written discussion, in accordance with the established practice of the Society. The first portion of the discussion by Mr. Devine was presented at the meeting as additional matter supplementing his own paper, which was published in the June issue of THE JOURNAL. The second part of his discussion was submitted subsequent to the meeting in the form of written discussion. Remarks by Mr. Bohner were presented at the meeting in the form of written discussion.

TO be invited to present a paper before such a representative gathering of the automotive industry is indeed an honor; but, when the invitation is predicated upon the assumption that the subject is of National importance, then truly does the speaker realize he is but a modest luminary amidst a galaxy of shining lights.

Obviously, some members of the Society are at variance with the conclusions of those of us who have been styled "proponents of multiple focusing"; else why should it be suggested that the "desirability" of two focusing mechanisms be discussed, rather than the "necessity"? What sudden change of heart has so swiftly stricken lamp or motor-car manufacturers as to make this 5-or-10-cent detail a matter of National importance?

The most encouraging thought to be gleaned from the invitation is that at last a few members of the industry, at least, have awakened to the fact that the head-lamps on an automobile are important. Although the particular question at issue might be definitely settled at this meeting, it is hard to believe that we should be any nearer the goal toward which all enforcement authorities are striving; that is, the elimination of the present menace to night driving.

Judging from past performances at many similar meetings I have attended, prepared papers receive the usual amount of respectful attention and enough applause to satisfy the speaker showered upon him, but the engineer returns to his factory and continues to make the head-lamp relatively the cheapest thing on the car.

ATTITUDE OF MANUFACTURERS

I am not a hopeless pessimist, but as a member of the Lighting Committee of the Eastern Conference of Motor-Vehicle Administrators since its organization, and as the officer in the Pennsylvania Bureau of Motor Vehicles

[1] Chief inspector, Pennsylvania Bureau of Motor-Vehicles, Harrisburg, Pa.

charged with the approval or rejection of automobile headlighting devices and headlight enforcement, I am distinctly "fed up" with these chaps who come in with a tin can, a near-lamp and a piece of glass and protest volubly that they are with us in the fight for better head-lamps. They would build them better if the competition were not so keen; they have to give the motor-car manufacturer what he asks for; why should they have to put this gasket in, if So-and-So does not? You all have the same line of talk and it is seldom varied with a real earnest desire to give the motorist something for his money.

All of which goes to prove, as I have long contended, that the automobile industry is comprised of the largest aggregation of copyists in existence. What the other fellow has, we must have; no more, but less, if we can make it look the same and get by with it. Witness the great rush some years ago from lenses to reflectors; then to the double-filament lamp. Nowadays a purchasing agent will not look at a head-lamp unless it is shaped like a bullet, a cone or a kettle-drum. It is a safe bet that, if any one of the more generally used cars came out with an arc-light as standard equipment, you would all be using it in a few months.

Double-Filament Lamps a Doubtful Development

Aside from the merits of this discussion, has there been any real improvement in automotive headlighting? Is it not a fact that we are still confronted with the same old and troublesome problems? That is, cheap and poor construction, faulty and complicated adjustments, not enough or too much intensity at certain points, and, worst of all, the general impression that the motorist does not know what it is all about anyhow, but his car would not look right without lamps, so give him anything, but be sure it *looks* like what the other fellow is giving him.

Happily, there are a few who are making some effort to improve conditions, but too often even they are forced to submit to the general trend or go out of business. Some of you may have heard me express the opinion that what the head-lamp business needed was a "czar" who would tell you what you should build and how much you should charge for it and make you stick to it. I have been told that is too Utopian for the automotive industry, and perhaps it is like that other dream I have had that some day lighting equipment would be featured in automobile advertising. I am not surprised that it is not done now, because there is not much to talk about; but the surprise is that the lamp manufacturer permits his product to be sidetracked in favor of other devices perhaps less worthy of mention. He is contributing one of the most vital safety factors in the construction of motor-vehicles, yet he does not insist that it be played up". Right there, I believe, the industry is losing the one thing which will go far to solve our problems—pride of product.

The commonly termed "double-filament head-lamp" was widely heralded as a far-reaching development, but I am rapidly being led to the conclusion that, as now designed, constructed and used, it has fallen far short of that mark, and that the innocent and long-suffering motoring public is again "holding the bag."

Those of us who are urging double adjustment have been accused, among other things, of attempting to hamper development and of a desire to restrict the use of such head-lamps. Perhaps it would be a good thing if we did; and this is said with the knowledge that I assented to having certain of these lamps placed on the approved lists of the member States of the Eastern Conference. However, I emphatically deny that the Conference, or its Lighting Committee, was ever actuated by any such motive.

Many of these accusations, and much of the propaganda in this connection, result from the fact that in the majority of cases the cooperation of head-lamp and incandescent-lamp manufacturers, from whom the Conference might expect to receive the most constructive and unbiased conclusions on the subject, has been limited to their personal interests, usually based on or expressed from the commercial viewpoint.

Inaccuracy in Axial Alignment

About 4 years ago I viewed what was to me the first demonstration of this double-filament idea, and it was the consensus of opinion at that time that it was a problem that would be liable to develop a great deal of trouble. Even the applicants for approval of that device afterward admitted it was horrible, and, if memory serves me correctly, later endeavored to deny sponsorship. With the advent of the first device of this kind that showed a serious attempt to meet the desires of the Conference Lighting Committee and give the motorist something akin to what he thought he was getting, the question of single versus double mechanisms presented itself as an issue.

At that time enforcement authorities were virtually without previous experience regarding the practical working of these lamps or the manufacturing difficulties attendant upon their construction. Hence we had no guide for our regulations or specifications and, as a matter of fact, the head-lamp first approved was originally designed without a vertical-focusing mechanism because, as I recall it, the manufacturer was informed that double-filament lamps would be held to a tolerance of 1½ sixty-fourths of an inch on axial alignment. This was later refuted by the lamp manufacturers, who stated that the manufacturing limit for accuracy would be from 3/64 to 4/64 in.

Because of these vague possibilities and their potentialities for causing trouble, it was suggested that an adjustment be used to locate the filaments properly. And, incidentally, one of the present vigorous opponents of the double adjustment was then chairman of the Conference Lighting Committee which sponsored the specifications incorporating this requirement and forming a part of the certificates of approval for this particular head-lamp.

Our conjectures at that time seem to have been borne out, because now there is considerable urging on the part of lamp manufacturers that we adopt a tolerance of 3/64 in., and it will be remembered that, even after agreement to hold to certain specified tolerances, certain incandescent-lamp manufacturers were compelled, through the action of the Conference, to recall more than 100,000 lamps on the market, which were admitted to be so poor that they were destroyed. What assurances have we that this will not again occur? Enforcement officers must be constantly on guard for such possibilities, since they evidently are not guarded against by manufacturers, and certainly will not be caught by the layman or average unsuspecting motorist.

Insensitive Head-Lamps Not Yet a Reality

It has been argued that insensitive head-lamps are now a reality. Then indeed are we approaching the millennium! One such tilting-beam head-lamp for which these claims are made is now on the approved list of the

TABLE 1—SUMMARY OF INCANDESCENT-LAMP TESTS WITH TILT-RAY HEAD-LAMPS

Lamp, No.	Name	Date Purchased or Supplied	Test Date	June 14, 1926								June 15, 1926				June 16, 1926			June 21, 1926				
				1[a]			2[b]			3[c]		4[d]			5[e]			6[f]			7[g]			8[h]	
			Lamp Position	Upper Beam		Tilt, Deg.	Upper Beam		Tilt, Deg.	Upper Beam		Upper Beam		Tlt, Deg.	Upper Beam		Tilt, Deg.	Upper Beam		Tilt, Deg.	Upper Beam		Tilt, Deg.	Upper Beam		Tilt, Deg.
				Raised, In.	Low-ered, In.		Raised, In.	Low-ered, In.		Raised, In.	Low-ered, In.	Raised, In.	Low-ered, In.		Raised, In.	Low-ered, In.		Raised, In.	Low-ered, In		Raised, In.	Low-ered, In.		Raised, In.	Low-ered, In.	
1[i]	Edison Mazda	May 24, 1926	Normal	.....	2	+2½	.....	6	+1	....	4	1½	OK.	OK.	+2	OK.	OK.	+2½	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2
			Reversed	12	.....	+3	4	.....	−3	6	....	+2½	6	....	+2½	8	....	−3	12	....	3½	6	....	+2½	OK.	OK.	+2
2[j]			Normal	.....	2	2	.....	7	+1	OK.	OK.	2	....	3	+2	OK.	OK.	2	OK.	OK.	−2	OK.	OK.	+2	OK.	OK.	2
			Reversed	11	.....	+3½	OK. Hazy	OK. Cut-off	2	5	....	−3	6	....	−2	10	....	+3	10	....	−3	6	....	+2	OK.	OK.	2
3[k]			Normal	8	.....	−3	OK.	OK.	2	1	....	−2½	5	....	+2	6	....	+2½	7	....	−2½	5	....	+2½	OK.	OK.	2
			Reversed	OK. Hazy	OK. Cut-off	2	.....	2	2	OK.	OK.	+2	1	....	−2½	OK.	OK.	2	1	....	2	OK.	OK.	+2	OK.	OK.	+2
4[l]	Westinghouse	May 24, 1926	Normal	6	.....	+2½	.....	2	2	1	....	−2½	6	....	+2½	1	....	+2½	6	....	+2	2	....	+2	OK.	OK.	2
			Reversed	6	.....	+3	OK.	OK.	2	4	....	−3	3	....	−3	6	....	−3	4	....	−3	5	....	−2½	OK.	OK.	+2
5[l]			Normal	6	.....	3	4	.....	+2½	2	....	2½	8	....	3	4	....	−3	10	....	−3	5	....	−3	OK.	OK.	+2
			Reversed	OK.	OK.	2	OK.	OK.	2½	OK.	OK.	2	2	....	3	2	....	+2	5	....	−3	4	....	−3	OK.	OK.	+2
6[m]	Edison	Nov. 24, 1926	Normal	6	.....	3½	OK.	OK.	2	1	....	−2½	3	....	−3	5	....	+2½	6	....	−3	4	....	−2½	OK.	OK.	+2
			Reversed	3	.....	2½	OK.	OK.	2	OK.	OK.	2	.....	.....	.....	1	....	+2	2	....	+2	OK.	OK.	+2	OK.	OK.	2
17[i]	Tung-Sol	May 22, 1926	Normal	OK.	OK.	2	.....	6	1	....	2	2	OK.	OK.	2	1	....	+2	1	....	+2	OK.	OK.	2	OK.	OK.	2
			Reversed	OK.	OK.	2	OK.	OK.	2	1	....	2	OK.	OK.	2	2	....	+2½	2	....	−1½	1	....	+2	OK.	OK.	2
18[n]	Mazda	Mar. 22, 1926	Normal	6	.....	+3	OK.	OK.	2	OK.	OK.	2	4	....	+2	6	....	+2½	6	....	+2	5	....	+2½	OK.	OK.	2
			Reversed	2	.....	+2½	.....	3	2	OK.	OK.	2	OK.	OK.	2	1	....	−2½	1	....	2	1	....	−2½	OK.	OK.	+2
19[o]	Westinghouse	Nov. 23, 1925	Normal	3	.....	+2½	.....	4	1½	....	1	2	OK.	OK.	2	2	....	+2	2	....	−2½	1	....	+2	OK.	OK.	2
			Reversed	6	.....	−3	2	.....	−2½	3	....	+2½	5	....	+2½	5	....	+2½	6	....	+2	4	....	+2½	OK.	OK.	2
20[n]	National	Nov. 23, 1925	Normal	6	.....	−3	OK.	OK.	2	OK.	OK.	2	1	....	−2½	4	....	+2½	3	....	−2½	OK.	OK.	+2	OK.	OK.	+2
			Reversed	3 Hazy	..... Cut-off	+2½	.....	2	1½	1	....	−2½	4	....	−3	5	....	−2½	6	....	−2½	5	....	−3	OK.	OK.	+2
21[n]			Normal	7	.....	+2½	2	.....	+2½	4	....	−3	5	....	+2	4	....	−3	5	....	+2	6	....	−2½	.....	.....	.....
			Reversed	1	.....	2	.....	6	1½	....	3	−2	OK.	OK.	+2	1	....	−2½	OK.	OK.	−2	OK.	OK.	+2	.....	.....	.....
22[n]	Tung-Sol	Nov. 23, 1925	Normal	3	.....	+2½	OK.	OK.	2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	+2	2	....	+2	OK.	OK.	+2	.....	.....	.....
			Reversed	OK. Hazy	OK. Cut-off	2	.....	2	1½	1	....	+2½	4	....	2	4	....	−2½	5	....	−2½	4	....	+2	.....	.....	.....
23[n]			Normal	2	.....	−2½	.....	2	2	OK.	OK.	+1½	OK.	OK.	−1½	OK.	OK.	+2	3	....	−2	OK.	OK.	2	.....	.....	.....
			Reversed	.....	2	−1	.....	5	1	OK.	OK.	2	OK.	OK.	2	OK.	OK.	+2	2	....	−2	OK.	OK.	2	.....	.....	.....
25[o]	Edison	Nov. 19, 1925	Normal	4	.....	−3	OK.	OK.	2	5	....	+3	5	....	−3	4	....	−3	5	....	−2½	3	....	−3	.....	.....	.....
			Reversed	6	.....	−3½	OK.	OK.	2	OK.	OK.	2½	5	....	+2½	6	....	+3	6	....	−3	6	....	−3½	.....	.....	.....
26[p]	National	Nov., 1925	Normal	6	.....	+3	OK.	OK.	2	2	....	−3	1	....	+2	2	....	+2½	5	....	−3	3	....	−3	.....	.....	.....
			Reversed	6	.....	+3	OK.	OK.	2	3	....	3	3	....	+2½	4	....	−3	6	....	−2½	4	....	−3	.....	.....	.....
27[q]		Dec. 28, 1925	Normal	4	.....	+2½	.....	2	2	OK.	OK.	2	4	....	+2	OK.	OK.	+2	5	....	−2½	2	....	+2½	.....	.....	.....
			Reversed	4	.....	+2½	.....	2	2	1	....	−2½	1	....	+2	2	....	+2½	4	....	−2	3	....	+2½	.....	.....	.....
28[r]		Aug. 18, 1925	Normal	10	.....	+3½	1	.....	−2½	6	....	+3	6	....	+2½	6	....	+2½	7	....	+2½	6	....	+3	.....	.....	.....
			Reversed	OK.	OK.	2	.....	4	−2	OK.	OK.	−2½	1	....	−2½	2	....	+2½	4	....	−3	2	....	+2½	.....	.....	.....
29[s]		Mar. 20, 1926	Normal	OK.	OK.	2	.....	2	−2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	+2	2	....	−2½	1	....	2	.....	.....	.....
			Reversed	6	.....	+3	OK.	OK.	2	1	....	−2½	6	....	−2½	6	....	−2½	7	....	+2½	7	....	+2½	.....	.....	.....
30[t]		1924	Normal	OK.	OK.	2	.....	5	1½	OK.	OK.	2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	2	OK.	OK.	+2	.....	.....	.....
			Reversed	10	.....	−3	OK.	OK.	2	5	....	2	8	....	+2½	7	....	−3	12	....	−3½	7	....	−3	.....	.....	.....
31[u]		Apr. 16, 1926	Normal	6	.....	+3	.....	1	2	1	....	−2½	3	....	+2½	2	....	+2½	5	....	−3	3	....	+2½	.....	.....	.....
			Reversed	2	.....	+2½	.....	3	1½	OK.	OK.	−2½	2	....	−2½	OK.	OK.	+2½	4	....	+2½	2	....	+2½	.....	.....	.....

[a] First sample submitted by Guide Motor Lamp Mfg. Co., January, 1925.
[b] Second sample, submitted March 28, 1925.
[c] Buick style, 7⅞-in. door-opening, submitted May 22, 1926.
[d] Chrysler style, submitted Feb. 25, 1926.
[e] Reo style, submitted April, 1926.
[f] Buick style, submitted in the autumn of 1925.
[g] Proposed Studebaker style, submitted by Edmunds & Jones Corporation, June 7, 1926.
[h] Buick style, with vertical adjustment and 7⅞-in. door-opening, submitted Dec. 20, 1925.
[i] Purchased from Philadelphia Electric Co.
[j] From H. G. Roberts Electric Supply Co., Philadelphia.
[k] Purchased from J. H. McCullough & Son, Philadelphia.
[l] Submitted with sample production of Tilt Ray lamps by Guide Motor Lamp Mfg. Co.
[m] Submitted with Depress Beam original test lamps by Edmunds & Jones Corporation.
[n] Furnished by R. N. Falge, National Lamp Works of the General Electric Co.
[o] Furnished by L. C. Porter, Edison Lamp Works of the General Electric Co.
[p] Submitted with first sample of Duralite lamp by Macbeth-Evans Glass Co.
[q] Submitted with first sample of Duray lamp by T. J. Corcoran Lamp Co.
[r] Submitted with first sample of Twolite lamp by McKee Glass Co.
[s] Submitted with sample production of Parabeam lamps by Parafiector Co.
[t] Submitted with first sample of Turn Beam lamp by Monogram Lens Corporation.
[u] Submitted with first sample of Dulux lamp by J. W. Brown Mfg. Co.

TABLE 2—PENNSYLVANIA TEST-DATA ON

Laboratory Report, No.	Head-lamp	Type	Lower Beam Raised	Candlepower Values at Illuminating Enginering Society Test-Points											
				A			B			C			D		
				Minimum 1,800 | Maximum 6,000			Minimum 7,200			Minimum 800 | Maximum 2,400			Maximum 800		
			Difference, Deg.	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal
44676	Tilt Ray	Chrysler	2½	5,800	840	3,200	26,000	1,090	10,700	880	640	1,300	560	480	780
44444		Small Buick	2	5,400	.....	.....	31,000	.....	.....	850	.....	.....	520	.....	.....
43464		Large Buick	.....	2,800	.....	3,200	19,500	.....	9,100	800	.....	1,640	440	.....	780
44707	Parabeam	Packard 6	2½	3,000	860	4,800	18,000	1,510	10,400	940	680	2,100	460	540	1,100
44215			2½	5,200	.....	2,900	15,500	.....	7,400	930	.....	1,560	590	.....	860
44210	Twin Beam	Small Cadillac	2½	4,200	.....	2,700	12,500	.....	9,800	1,080	.....	1,300	550	.....	790
44530	Dualite		2	5,900	850	3,700	31,000	1,720	12,200	960	530	1,720	680	450	1,200
44703	Duray		2½	4,600	710	3,400	18,200	1,200	7,500	950	530	1,750	800	440	1,450
44552	Twolite		.....	4,500	1,450	.....	16,800	4,000	.....	860	660	.....	700	600	.....
44806	Twolite (New)		2	3,800	920	3,600	33,000	1,840	13,000	1,070	680	1,840	560	500	1,060
44673	Depress Beam		2	4,500	1,060	4,000	33,000	2,050	8,600	870	690	2,050	720	580	1,350
44717	Dulux		2½	5,100	1,230	5,000	14,000	1,660	17,300	1,840	880	2,000	620	430	780
44755	Parabeam	Nash	2½	5,500	880	2,500	18,200	1,690	7,900	990	690	1,370	430	580	770
44754		Packard 8	2	5,200	1,130	2,200	20,500	1,630	7,000	1,180	800	1,630	510	660	1,080
44751		Packard 6 New	2	5,200	970	3,100	19,000	1,560	7,200	1,330	700	1,560	610	560	1,070

Conference States, and when originally submitted did not have a vertical-adjusting mechanism. For this and other reasons Conference approval was withheld for some time, and then granted only because of a statement by the manufacturer that

> No vertical filament-adjustment is necessary in this lamp because it is designed to and does retain its tilting ability even though the variation in vertical location of the filament is as much as ⅛ in.

This also was in that period when no previous practical experience was available, and this statement, coupled with the assumption that lamps would be held within a tolerance of 4/64 in., was accepted in good faith.

In requiring two adjustments on the first device, we were seeking protection against a then unknown, but suspected, difficulty, and when the second device was submitted there were those of us who were not entirely sure that this difficulty, or its cause, had been removed. Later developments seem to have vindicated our judgment, and the data assembled in Pennsylvania Chart No. 2 (see Table 1), by Pennsylvania inspectors after exhaustive tests and research are particularly interesting, especially in view of the fact that proponents of single adjustment have not yet been able to explain away some of the peculiar results found. Consequently, we are not to be censured for assuming that some other head-lamp subsequently approved, and perhaps of more intricate design and construction, will perform in the same eccentric manner.

It is here interesting to note that, with these two types approved and on the market, the next two-filament device to be submitted incorporated two adjustments. In the meantime, a period had ensued within which comparisons could be made, and it is evident that the engineers developing this particular device were convinced of the necessity for the vertical adjustment. I am informed that later experiments of these same engineers have confirmed this belief; and to say, as has been claimed, that "no competent illuminating engineer has, in the light of actual practical service-conditions, supported the considerations involved" in the position taken by the proponents of the double adjustment, is to impugn the experience and judgment of many of those present.

In a most casual summary it is possible at the present time to name at least 16 automobiles of standard and widely used makes for which double-adjustment headlamps have been adopted, as against 6 makes which are equipped with single-adjustment head-lamps. However much some of us may feel that safety on our highways is often subordinated to price considerations, there nevertheless must be some technical reasons for such a marked divergence of opinion among those persons whose sole object is to cater to the desires of the motoring public.

Instructions Not More Complicated

It will be, and has been, argued that clear and direct instructions cannot be issued by motor-vehicle authorities for the use of two adjustments. This, on its face, seems to be a specious argument, developed merely to becloud the issue. If true, it is a serious reflection upon the ability of one of the principal sponsors of the double-filament lamp who was instrumental in preparing the instructions for one of the first two-adjustment headlamps approved. Further, I am wondering how this situation is handled in those States which by reason of their laws must appoint and instruct official adjusting-stations, yet permit the use on their highways of headlighting devices with two adjustments. Are we to believe that they simply throw up their hands and allow the indiscriminate operation of cars with glaring headlamps?

In reviewing my press clippings in preparation for this address, I was surprised to find a news item from the Worcester, Mass., *Gazette* of April 13 relating the fact that two out of three automobiles tested April 12, at a headlight clinic in that city, were found to have defective lights, and, out of 714 automobiles tested, 476 were not properly adjusted. Surely not all of those out of adjustment were multiple-focusing devices!

I ask you if this bugaboo of "difficult instructions" is not a rather far-fetched argument; and, while we may sometimes think the motorist is dumb, in Pennsylvania, at least, we find that 95 per cent of our drivers are willing and anxious to obey our laws, and try to do what we tell them to do. We have ample authority to take care of the other 5 per cent. Incidentally, beginning with Jan. 1, 1928, the Pennsylvania Bureau of Motor-Vehicles will designate approved adjusting-stations, and I am sure our inspectors will not jeopardize their positions by inability to promulgate and disseminate the necessary instructions. In fact, we are now doing ex-

TWO-FILAMENT HEADLIGHTING EQUIPMENT

Laboratory Report, No.	Candlepower Value at Illuminating Enginering Society Test-Points												Maximum Candlepower						Head-lamp Specifications, Diameter, In.		
	P_l Minimum 5,000			P_r Minimum 5,000			Q_l Minimum 2,000			Q_r Minimum 2,000											
	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Lower Beam	Lower Beam Horizontal	Upper Beam Horizontal	Deg. Below "A"	Lower Beam	Deg. Below "A"	Lower Beam Horizontal	Deg. Below "A"	Reflecting Surface	Lens	Reflector Flange
44676	17,800	920	12,400	16,000	1,070	10,300	3,200	1,820	5,000	3,100	1,860	4,200	30,000	1¼	21,000	5	21,000	2½	7	8x6⅞	8
44444	15,000	.....	.....	14,400	.....	.....	3,400	.....	.....	3,500	.....	.....	31,000	1	21,000	5	.....	.....	7 1/16	7⅛	8⅛
43464	15,000	.....	7,300	17,000	.....	7,100	5,000	.....	6,400	5,800	.....	6,900	.....	.....	.....	.....	.....	.....	7¾	9	.....
44707	12,000	1,400	14,300	15,000	1,400	12,800	10,000	3,000	5,400	9,500	4,400	7,400	24,000	2¾	13,500	5	.....	.....	7½	9¼x7 11/16	.....
44215	11,700	.....	8,800	12,200	.....	8,900	9,700	.....	10,500	11,000	.....	13,000	.....	.....	.....	.....	.....	.....	8	.....	.....
44210	12,000	.....	12,000	11,200	.....	12,000	10,500	.....	11,300	11,500	.....	12,000	.....	.....	.....	.....	.....	.....	8⅛	9	.....
44530	15,000	1,960	12,000	13,300	1,660	12,000	8,700	4,100	6,000	8,200	3,900	6,000	32,000	1	16,200	5	.....	.....	8	9¼	.....
44703	17,000	1,570	9,600	17,500	1,490	9,000	4,800	2,700	9,200	4,800	2,000	8,600	19,000	1¼	14,000	5½	.....	.....	7¾	7½	.....
44552	17,000	4,500	.....	17,500	4,500	.....	7,800	6,000	.....	7,800	6,000	.....	18,200	1½	9,200	4½	.....	.....	8	8	.....
44806	18,500	1,960	14,900	19,000	2,100	13,800	7,400	4,900	4,100	9,600	5,000	6,000	33,000	1	23,000	4	.....	.....	8	9¼x7 11/16	.....
44673	16,600	2,350	9,000	18,800	2,400	8,600	4,300	2,800	6,100	4,900	2,450	5,400	33,000	1	26,000	4½	.....	.....	7½	7⅝	.....
44717	11,200	1,080	14,000	7,200	1,340	11,400	6,000	1,330	5,500	6,300	1,430	5,500	33,000	2½	28,000	5½	.....	.....	8½	9	.....
44755	15,500	1,030	6,000	15,400	1,200	7,700	7,800	910	10,500	9,200	1,460	7,700	21,000	1½	19,000	5¼	.....	.....	7	8x7 1/16	.....
44754	15,500	1,490	7,700	15,000	1,390	5,700	9,300	1,860	14,000	9,400	1,640	11,400	22,300	1½	20,800	4¾	.....	.....	9	10x8 11/16	.....
44751	17,000	1,620	6,400	13,000	1,640	6,600	9,600	2,100	11,900	8,400	2,100	11,000	24,000	1½	18,000	5	.....	.....	8½	9½x8 1/16	.....

actly this in an instruction course now under way with the municipal police of Pittsburgh.

The Pittsburgh authorities have designated six traffic officers as a headlight squad, and these, in company with six others from surrounding municipalities, are being given a course in head-lamp adjustment by one of our inspectors, similar to that given the "flying squadrons" of the Pennsylvania State Highway Patrol. Remember that these men are ordinary policemen, perhaps somewhat better than the average but certainly not mechanics or "approved adjusters", and then note this report from our inspector:

> I was impressed with the manner in which these fellows were able to adjust the two approved types of multiple-adjustment head-lamp after a short explanation. It can be done!

It is claimed that "one adjustment is the limit for practical operation by the motorist, or even by approved adjusters", and in the next breath we are told that, regardless of the focusing, the lamps must be properly aimed; so we have at least two operations. Which is the more important and, under present standards of manufacture, the harder to perform?

At this point I shall no doubt be accused of confusing the issue by attempting to use the vertical adjustment as an aiming device. Why not? So far as enforcement is concerned, is not the aiming of the head-lamp beams the feature which will determine whether or not they are projected into the eyes of approaching persons? The easier it is made for the car owner to regulate the angle of his beam, the more likely we are to have that beam inoffensive, and, with all due respect to your honorable body, the present S.A.E. mounting certainly presents a challenge to the ingenuity possessed by the average motor-car driver.

When a practical man indulges in theory, his statements are largely discounted, but many of you are familiar with my theory of what seems to be the ideal head-lamp. It must, of course, be one which complies with the laws, specifications and regulations, but when we insert an incandescent lamp, if the beam is too high we must be able to turn it down, and if too low, turn it up. That operation certainly would be within the range of the average driver's intelligence, and I am encouraged in my theory, which has been advanced freely and without any patent reservations for a number of years, by the fact that recent developments seem to show that this simple fact is filtering through the minds of head-lamp engineers.

If the efforts expended by head-lamp and automobile manufacturers in devising ways and means by which enforcement officials may be dragooned, harassed or led into an embarrassing position were concentrated upon the construction and marketing of the best possible type of complete head-lamp, the aims which we all seek would be accomplished. In the meantime, why are the advocates of single adjustment so solicitous of the car-owner's knowledge of this feature of his head-lamps? Has the simplification of adjustments on his carbureter or his four-wheel brakes assumed National importance? Does he learn those adjustments, or is there a particular reason for keeping him in ignorance of them? Certainly they are more intricate than taking a couple of turns on a screw with a screwdriver; and consider for a moment the aptitude of the average man with tools in his struggles with the S.A.E. mounting, which is his only present means of aiming the headlight beam.

Within the last 2 weeks, three Pennsylvania Highway Patrol headlight details stopped 921 passenger-cars, representing 47 makes, and out of this total it was found that 536 operators, or 57 per cent, knew the use of the adjustment screws. Only 145 of the total, or slightly more than 1 per cent, had ever personally used the nut under the S.A.E. mounting to tilt their head-lamps.

Use of Vertical Adjustment for Aiming

It has been claimed that the use of the vertical adjustment for aiming disregards the best adjustment of the incandescent lamp and results in a distortion of the beam. I shall attempt to show that this premise is incorrect, in that the vertical adjustment provides a quick method of properly aiming the beam and a correction for imperfect alignment of filaments in the lamp.

We are assuming that the idea of having adjustments of any kind on a head-lamp is not so that the car manufacturer can adjust the lamp properly, as he has facilities for placing it on the car in a predetermined position before the car leaves the factory; therefore, we must assume that the lamp is aimed properly when leaving the factory and that the need for the adjustment is so that the user of the car can obtain a quick and accu-

rate adjustment of the beam after replacing a burned-out lamp and can place this beam at the same level as the beam from the other lamp. It then follows that, if a lamp properly or improperly manufactured is placed in the head-lamp and focused by the usual method and the vertical-adjusting mechanism is used to position the lower filament relatively to the axis of the reflector so that the tops of both beams are at the same height, we have accomplished the double object of compensating for filament inaccuracies and aiming the head-lamp.

Adjustment in Practice

We seem to have disposed effectually of the arguments as to the difficulty of instruction in the use of two adjustments and of the alleged inconsistency in using the vertical adjustment as a means of aiming the head-

TABLE 3—SUMMARY OF DOUBLE-FILAMENT

Lamp No.	Name	Lamp Position	Tilt Ray						Dualite						Parabeam		
			1[a]			2[b]			3[c]			4[d]			5[e]		
			Upper Beam		Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.
			Raised, In.	Lowered, In.		Raised, In.	Lowered In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.	
1	Edison Mazda	Normal	OK.	OK.	2	OK.	OK.	2	.....	2	2	OK.	OK.	2	OK.	OK.	2
		Reversed	12	.....	+3	OK.	.....	+2	12	.....	3½	OK.	OK.	+2	OK.	OK.	1½
2		Normal	OK.	OK.	2	OK.	OK.	2	.....	5	−1½	OK.	OK.	+2	OK.	OK.	2
		Reversed	9	.....	+2	OK.	OK.	2	6	.....	2½	OK.	OK.	2	OK.	OK.	2
3		Normal	6	.....	+2½	OK.	OK.	2	6	.....	+2½	OK.	OK.	2	OK.	OK.	2
		Reversed	OK.	OK.	+2½	*OK.	OK.	+2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	2
4	Westinghouse Mazda	Normal	3½	.....	2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	+2	OK.	OK.	2
		Reversed	4	.....	3	OK.	OK.	+2	2	.....	+2½	OK.	OK.	+2	OK.	OK.	2
5		Normal	3½	.....	2	OK.	OK.	+2	10	.....	4	OK.	OK.	−3	OK.	OK.	Ind.
		Reversed	OK.	OK.	2	OK.	OK.	+2	2	.....	+2	OK.	OK.	+2	OK.	OK.	Ind.
6	Edison Mazda	Normal	5	.....	+2½	OK.	OK.	+2	6	.....	+2½	OK.	OK.	2	OK.	OK.	2
		Reversed	2	.....	2	OK.	OK.	2	OK.	OK.	+2	OK.	OK.	2	OK.	OK.	2
7[f]	Westinghouse Mazda																
10[m]	National Mazda							Wiring of lamp reversed in manufacture.									
11[n]	Edison Mazda																
17	Tung-Sol Bifocal	Normal	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2
		Reversed	4	.....	2	OK.	OK.	2	1	.....	+2	OK.	OK.	+2	OK.	OK.	2
18	Mazda	Normal	2	.....	2	OK.	OK.	2	5	.....	−3	OK.	OK.	+2	OK.	OK.	2
		Reversed	OK.	OK.	2	OK.	OK.	+2	2	.....	+2	OK.	OK.	+2	OK.	OK.	2
19	Westinghouse Mazda	Normal	2	.....	+2	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2	OK.	OK.	2
		Reversed	OK.	OK.	2	OK.	OK.	2	4	.....	−3	OK.	OK.	+2	OK.	OK.	2
20	National Mazda	Normal	2½	.....	+2	OK.	OK.	+2	OK.	OK.	+2	OK.	OK.	2	OK.	OK.	Ind.
		Reversed	2	.....	+2	OK.	OK.	+2	5	.....	3	OK.	OK.	+2	OK.	OK.	Ind.
21		Normal	4	.....	2	.....	.....	.....	4	.....	2½	.....	.....	.....	OK.	OK.	2
		Reversed	OK.	OK.	2	.....	.....	.....	.....	6	2	.....	.....	.....	OK.	OK.	Ind.
22	Tung-Sol Bifocal	Normal	2	.....	+2	.....	.....	.....	OK.	OK.	+2	.....	.....	.....	OK.	OK.	Ind.
		Reversed	1	.....	+2	.....	.....	.....	4	.....	3	.....	.....	.....	OK.	OK.	2
23		Normal	OK.	OK.	2	.....	.....	.....	OK.	OK.	2	.....	.....	.....	OK.	OK.	2
		Reversed	OK.	OK.	2	.....	.....	.....	.....	1	+2	.....	.....	.....	OK.	OK.	2
24	Edison Mazda							Wiring of lamp reversed in manufacture.									
25		Normal	4	.....	2½	.....	.....	.....	2	.....	3	.....	.....	.....	OK.	OK.	+2
		Reversed	3	.....	3	.....	.....	.....	4	.....	3	.....	.....	.....	OK.	OK.	Ind.
26	National Mazda	Normal	2	.....	2	.....	.....	.....	5	.....	3	.....	.....	.....	OK.	OK.	2
		Reversed	3	.....	2½	.....	.....	.....	6	.....	+3	.....	.....	.....	OK.	OK.	2
27		Normal	OK.	OK.	2	.....	.....	.....	4	.....	3	.....	.....	.....	OK.	OK.	2
		Reversed	OK.	OK.	2	.....	.....	.....	OK.	OK.	2	.....	.....	.....	OK.	OK.	2
28		Normal	6	.....	−3	.....	.....	.....	6	.....	+3	.....	.....	.....	OK.	OK.	2
		Reversed	1	.....	2½	.....	.....	.....	OK.	OK.	2	.....	.....	.....	OK.	OK.	2
29		Normal	OK.	OK.	2	.....	.....	.....	OK.	OK.	2	.....	.....	.....	OK.	OK.	2
		Reversed	2	.....	2	.....	.....	.....	6	.....	+3	.....	.....	.....	OK.	OK.	+1
30		Normal	OK.	OK.	2	.....	.....	.....	.....	3	2	.....	.....	.....	OK.	OK.	+2
		Reversed	5	.....	2	.....	.....	.....	11	.....	+3	.....	.....	.....	OK.	OK.	2
31		Normal	1	.....	+2	.....	.....	.....	2	.....	+2½	.....	.....	.....	OK.	OK.	2
		Reversed	1	.....	+2	.....	.....	.....	5	.....	3	.....	.....	.....	OK.	OK.	Ind.

[a] Made with head-lamp centers 36-in. from the road surface and with a 25-ft. throw of the beam.

[b] Indefinite cut-off to low beam.

[c] Buick style, 7¾-in. door opening. Submitted by Guide Motor Lamp Mfg. Co., May 22, 1926.

[d] With vertical adjustment; 7⅛-in. door-opening. Submitted Dec. 20, 1926.

[e] With 8-in. door-opening. Samples from J. J. Shanley, June 5, 1926.

[f] With vertical adjustment; 8-in. door-opening. Submitted by C. M. Hall Lamp Co., Dec. 5, 1925.

[m] With 8½-in. door-opening. Submitted by Paraflector Corporation, June 3, 1926.

[n] With 8-in. door-opening. Submitted by McKee Glass Co., May 21, 1926.

lamps. Let us now turn to the question of adjustment in practice. It is not my purpose here to deal with the various methods of focusing and adjusting head-lamps, as in such a gathering as this it is assumed that these principles are understood thoroughly.

There is no question that many factors enter into the proper adjustment of head-lamps and that they depend largely upon correct and accurate construction. In theory, and in laboratory or experimental tests, it might be admitted that certain types of double-filament head-lamp will do what is claimed for them, but it must be remembered that laboratory readings usually are made with perfect head-lamps, reflectors and incandescent lamps and that the tests are conducted under ideal conditions, while production lamps are often far from perfect and must be used under all conditions.

21-CP. INCANDESCENT-LAMP TESTS[2]

Lamp, No.	Twolite			Depress Beam									Duray			Twin Beam		
	6[f]			7[g]			8[h]			9[i]			10[j]			11[k]		
	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.	Upper Beam		Vertical Adjustment Tilt, Deg.
	Raised, In.	Lowered, In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.		Raised, In.	Lowered, In.	
1	OK. OK.	OK. OK.	3 2½	1 6	.....	Ind.[3] Ind.	 1	5	+1 Ind.	OK. OK.	OK. OK.	Ind.[3] Ind.	OK. 6	OK.	1½ −2½	OK. OK.	OK. OK.	2 +2
2	OK. OK.	OK. OK.	3½ 3	OK. 6	OK.	Ind. +2	..... OK.	6 OK.	Ind. Ind.	OK. OK.	OK. OK.	Ind.	OK. 6	OK.	2 −2½	OK. OK.	OK. OK.	+2½ 2
3	OK. OK.	OK. OK.	2½ 2½	6 1	....	Ind. Ind.	OK.	OK. 3	Ind. Ind.	OK. OK.	OK. OK.	Ind. Ind.	6 OK.	..... OK.	Ind. 2	OK. OK.	OK. OK.	Ind. Ind.
4	OK. OK.	OK. OK.	2½ 3	7 4	....	Ind. Ind.	OK. OK.	OK. OK.	Ind. Ind.	OK. OK.	OK. OK.	Ind. Ind.	5 6	....	Ind. 2	OK. OK.	OK. OK.	2 Ind.
5	OK. OK.	OK. OK.	3½ 3	12 4	....	3 Ind.	3 OK.	..... OK.	Ind. Ind.	OK. OK.	OK. OK.	Ind. Ind.	6 4	....	Ind. Ind.	OK. OK.	OK. OK.	1½ 1½
6	OK. OK.	OK. OK.	3½ 3½	5 2	....	Ind. Ind.	OK. 5	OK.	Ind. Ind.	OK. OK.	OK. OK.	Ind. Ind.	2 OK.	..... OK.	Ind. 1½	OK. OK.	OK. OK.	2 +2½
7[l] 10[m] 11[n]	Wiring of lamp reversed in manufacture.																	
17	OK. OK.	OK. OK.	3½ 2½	3 2	....	1½ Ind.	..... OK.	4 OK.	Ind. Ind.	.....	.....	.....	OK. 2	OK.	Ind. Ind.	.....	.....	.....
18	OK. OK.	OK. OK.	+2½ 3	6 2	....	2½ Ind.	OK	OK. 3	Ind. Ind.	.....	.....	.....	5 3	....	Ind. Ind.	.....	.....	.....
19	OK. OK.	OK. OK.	+2½ +3	3 6	....	Ind. 2½	..... OK.	3 OK.	Ind. Ind.	.....	.....	.....	4 5	....	Ind. 2	.....	.....	.....
20	OK. OK.	OK. OK.	2½ +3	1 7	....	Ind. −2½	..... OK.	4 OK.	Ind. Ind.	.....	.....	.....	3 1	....	Ind. +2	.....	.....	.....
21	OK. OK.	OK. OK.	2½ 3	5 1	....	Ind. Ind.	OK.	OK. 4	Ind. Ind.	.....	.....	.....	6 OK.	..... OK.	Ind. Ind.	.....	.....	.....
22	OK. OK.	OK. OK.	2½ +2½	2 5	....	Ind. Ind.	....	4 2	Ind. Ind.	.....	.....	.....	OK. 2	OK.	Ind. Ind.	.....	.....	.....
23	OK. OK.	OK. OK.	2½ +2½	2 1	....	Ind. Ind.	....	4 3	Ind. Ind.	.....	.....	.....	2 OK.	..... OK.	Ind. Ind.	.....	.....	.....
24	Wiring of lamp reversed in manufacture.																	
25	OK. OK.	OK. OK.	3 +2½	6 7	....	2 2	OK. 1	OK.	−1½ Ind.	.....	.....	.....	5 5	....	2 Ind.	.....	.....	.....
26	OK. OK.	OK. OK.	3 +2½	5 5	....	Ind. Ind.	..... OK.	3 OK.	Ind. Ind.	.....	.....	.....	6 5	....	Ind. Ind.	.....	.....	.....
27	OK. OK.	OK. OK.	+2½ +2½	5 5	....	Ind. Ind.	..... OK.	3 OK.	1½	.....	.....	.....	2 OK.	..... OK.	Ind. Ind.	.....	.....	.....
28	OK. OK.	OK. OK.	3 3	8 4	....	+2½ Ind.	1	 2	Ind. Ind.	.....	.....	.....	6 1	....	Ind. Ind.	.....	.....	.....
29	OK. OK.	OK. OK.	2½ +2½	4 7	....	Ind. Ind.	 1	5	Ind. Ind.	.....	.....	.....	OK. 6	OK.	Ind. Ind.	.....	.....	.....
30	OK. OK.	OK. OK.	+2½ +3½	OK. 12	OK.	Ind. Ind.	 3	6	Ind. Ind.	.....	.....	.....	OK. 7	OK.	Ind. Ind.	.....	.....	.....
31	OK. OK.	OK. OK.	+2½ +2½	4 5	....	2 Ind.	1 OK.	..... OK.	Ind. Ind.	.....	.....	.....	4 2	....	Ind. Ind.	.....	.....	.....

[g] With 7⅜-in. door-opening. Submitted by Edmunds & Jones Corporation, April 7, 1926.

[h] With 7⅜-in. door-opening. Submitted by Edmunds & Jones Corporation, June 21, 1926.

[i] With vertical adjustment; 7⅜-in. door-opening. Submitted by Edmunds & Jones Corporation, June 21, 1926.

[j] With 7½-in. door-opening. Submitted by T. J. Corcoran Lamp Co., April 2, 1926.

[k] With 7⅛-in. door-opening. Submitted by Monogram Lens Corporation, June 11, 1926.

[l] Purchased from Gol-Mar Supply Store, Philadelphia.

[m] Supplied by R. N. Falge, National Lamp Works of the General Electric Co.

[n] Supplied by L. C. Porter, Edison Lamp Works of the General Electric Co.

One of the arguments against the use of a vertical-adjusting mechanism is that it will be accompanied by additional manufacturing inaccuracies which cause trouble in service; and this serves to show that this argument evidently is based on the production of a perfect head-lamp. Our experience has shown that production lamps and head-lamps often perform in an entirely different manner from that of those tested in the laboratories. We even find faulty construction in samples submitted for approval, which, because they are in many cases hand-made, should be that much more accurate. (See Table 2.) Sockets will vary up to and beyond a variation precluding any possibility of holding the filaments of a two-filament lamp within 3/64 in. of a predetermined position; so this argument is more of a generality with regard to all head-lamps than a specific fault with those incorporating the double adjustment.

We will admit that many head-lamps now in service are not adjusted, even though such an admission casts reflection upon the enforcement authorities. A reported analysis of the condition of the head-lamps on 1156 vehicles which were stopped in succession in 1925 in the State of Massachusetts, showed 41 per cent improperly focused, and it is claimed that if this condition were general it would mean that, if all head-lamps had multiple focusing-adjustments, 41 per cent of them, as a group, would be in worse condition than if all head-lamps had one adjustment.

In Pennsylvania, we are inclined to think that we better this record to a slight degree, because the reports from our headlight squads and checks made by impartial observers assure us that we have slightly more than 50 per cent of our head-lamps in proper adjustment. However, granting that only 41 per cent of the head-lamps in use are in adjustment, that is another argument to show that the old type of adjustment; namely, focusing with the focusing screw and aiming with the S.A.E. mounting, is unsuccessful. I will venture to say that an analysis of a majority of these cases would show, not so much that the incandescent lamps were improperly focused, as that the head-lamp beams were aimed too high.

It is claimed that those who have had experience in adjusting head-lamps cannot understand the proper use of multiple focusing-adjustments. In a check test, taken at certain approved adjusting-stations, the report is quoted as follows:

> In each case they focused the lamp with the upper screw and aimed the beam with the lower screw, instead of focusing the lamp with both screws and aiming it with the swivel bracket designed for that purpose.

Does it not seem that these mechanics chose the easier and quicker way rather than loosen up the entire lamp and lose the ground, following which the light would go out and they could not see where the beam was being aimed? And does it not follow that, if a head-lamp were designed with a vertical-adjusting mechanism for aiming, the average motorist would be more inclined to use it than to attempt the use of the S.A.E. mounting? After all, these mechanics reflected only a general sentiment and should not, in my opinion, be censured because they chose a practical, rather than a theoretical, means.

There is no denial that real improvement can be obtained only when head-lamps are constructed so that the necessity for any scientific knowledge on the part of the operator is eliminated, but I do not see that the situation with regard to double-filament lamps is made any clearer for him by eliminating the vertical adjustment. He is still left with the burden of focusing and aiming, both of which are vague operations to him; and, to make it more mysterious, the opponents of double adjustment give him nothing in return for taking this additional means away except to say, in effect, that if the desired results are not obtained, an improvement may be noticed by turning the incandescent lamp over. They don't even tell him why that improvement, if any, is the case, because that would not be good advertising for the lamps. And what does he think when he turns the lamp over and finds the results are not improved but, on the contrary, are sometimes even worse, as may be seen from Pennsylvania Chart No. 1, given in the accompanying Table 3?

There is an extreme degree of solicitude for the car-owner's knowledge of how to do this job correctly; then the means of doing it is taken away from him without even going to the trouble of telling him why. If it is a question of difficulty in issuing instructions, it seems to me just as difficult to explain how, when, and under what conditions to turn the lamp over as to demonstrate how to use the vertical-adjusting screw. Granting that it may take some little detail to explain the process, if it becomes necessary we can adopt the practice of the tabloid newspapers and "say it with pictures."

Future Development Not Retarded

I deny that future development and improvement in automobile headlighting will be retarded by an additional vertical-focusing adjustment through the removal of the incentive for the elimination of manufacturing variations. As a matter of fact, I believe that already the action of the Eastern Conference of Motor-Vehicle Administrators has stimulated the development and has resulted in various movements to invent, or at least experiment with, new and heretofore unused methods of projecting light in front of motor-vehicles. The very fact that I am followed on this program by a speaker who will present arguments for a fixed-focus development is an indication of the trend.

If our insistence on two adjustments has pointed the way to the construction of satisfactory devices with the minimum of adjustments and a resulting diminution of the operations necessary by the car owner or his mechanic, I think we are to be congratulated on our stand.

The threat has been made that if the vertical adjustment is required the manufacturer who is working under keen competition will pay little heed to accurate construction, but it is forgotten that nowadays the consumer is demanding more for his money; and it is also forgotten that enforcement authorities have the power to regulate the construction of head-lamps. Furthermore, if this vertical adjustment is not required, what assurances have we that incandescent-lamp tolerances will not be taken off and lamps made in any manner? If certain specified tolerances are agreed to, how are State authorities to know which and how many lamp manufacturers are bound by the agreement, particularly since some of the larger manufacturers admit that they have no control over their licensees in this respect?

The alleged purpose of a double-filament head-lamp was to afford relief for the oncoming driver. And, as enforcement authorities, we may impose any reasonable regulations to obtain proper relief. We are the ultimate judges of proper relief; and again, as enforcement officers serving the public's interest, we best serve that interest by prohibiting the use of headlighting devices shown by our tests and the admission of their manufacturers to be impossible of proper control in manufacturing. Realizing the variations, the competition and other factors en-

tering into the quantity production of two-filament head-lamps, we feel justified in the most stringent regulations to correct what the manufacturers admit they cannot control in commercial manufacturing.

It has never been contended that the vertical adjustment is a cure for all evils or a correction for all variations in light-source location. Perhaps, to obtain that objective, it may be that six focusing-adjustments would be necessary. Nevertheless, that does not alter the fact that two can be made the minimum requirement; nor that, if six were necessary and practical for enforcement purposes, they would have to be used. It does serve to prove, however, that it takes six corrections to make an accurate head-lamp of one which the motorist buys under the delusion that, when purchased, it is as nearly perfect as it can be made. Why not project the light correctly in the first place and give the car owner something for his money?

Some stress has been laid on the fact that Massachusetts has issued specifications for approval of two-filament lamps; and this is used as an argument for single adjustment. It seems that this is a negative argument. If no correction is necessary, and the single adjustment will take care of all manufacturing variations in incandescent lamps, why the necessity for such a specification?

Requirement of Two Adjustments Not Inconsistent

Much is made of the claim that the Conference resolution requiring vertical adjustment on all two-filament head-lamps is inconsistent and unjust, and of the additional claim that it is no more necessary on these head-lamps than it is with the same accuracy of construction in single-filament head-lamps.

I have been quoted as stating that I did not advocate the use of a second adjustment on a single-filament head-lamp because I did not feel that many of that type would be used in the future. At that time, and subsequently, I endeavored to obtain a consensus of opinion as to whether the double-filament head-lamp was the ultimate, and until just recently was assured, by practically all of the lamp manufacturers interviewed, that it was. I am not now so sure of it myself. But when it is inferred that in the face of the foregoing statement the 1926 Conference Lighting Committee, of which I was a member, recommended the approval, and the Conference approved, of one head-lamp of the single-filament type with a single focusing-adjustment and also approved another head-lamp with no focusing adjustment, I am compelled to draw attention to the fact that the Pennsylvania certificates of approval, at least, covering these two devices contain a provision whereby, if it is subsequently determined that a vertical-focusing adjustment is necessary, the manufacturer shall agree to incorporate it in the construction of these head-lamps. And I am reasonably certain that if the other member-States of the Conference followed the guidance of the Conference Lighting Committee their certificates contained the same provision.

This argument can easily be disposed of by the statement that, when the majority of single-filament devices were approved, we were not approving complete head-lamps. That, incidentally, is a Conference ruling which was not hailed exactly with joy by lamp manufacturers, again proving that as a group they are largely inclined to be reactionary as regards improvements, unless the issue is forced.

It is alleged that pressure directed by motor-vehicle administrators to secure such construction of head-lamps that night-driving conditions would be improved ought to be based on difficulties encountered in equipment in service. That is just what we have done in Pennsylvania; and it is what has been done in New Jersey.

Difficulties in Service and Resulting Research

In the summer of 1925, Benjamin G. Eynon, the Registrar of Motor-Vehicles for Pennsylvania, purchased a personal car equipped with double-filament head-lamps having only a single adjustment. He experienced considerable trouble with these, and as a direct result our inspectors were called upon to institute an exhaustive research into the practical performance of all double-filament lamps then approved or with approvals pending, using not only special incandescent lamps but stock lamps purchased in the open market. On the basis of data assembled in this investigation, made in collaboration with the State of New Jersey, the conclusion was reached that head-lamps and two-filament incandescent lamps, as now manufactured and sold, are of such a character that the results desired and claimed cannot be obtained unless some provision is made for accurate adjustment (see Tables 1 and 3).

These data have been used by the opponents of double adjustment in the claim that the question at issue has been exaggerated unreasonably as a result of unwarranted agitation. While it is distasteful to indulge in personalities, this statement cannot be passed without inquiring from whom the agitation has come. If memory serves me correctly, it was first started by the State of Massachusetts in issuing a bulletin to head-lamp manufacturers, following the action of the Conference in requiring two adjustments, to the effect that it did not look with favor upon any device submitted with more than one adjustment; and, subsequently, because it could not, or would not, recede from this viewpoint, Massachusetts withdrew from the Conference.

Prior to that action, however, the president of the Conference, realizing that there might be some merit in both sides of the question, arranged for a complete demonstration to be held at the July, 1926, Conference Meeting at Burlington, Vt., all sides of the question to be presented. The Lighting Committee, as then constituted, collected incandescent lamps purchased in the open market in many cities; also head-lamps and various data; and presented the case for double adjustment, evidently demonstrating its point to the satisfaction of the members, since the Conference ratified its action.

Massachusetts, although asked to attend, was not represented at this meeting which offered an unrestricted opportunity for an exhaustive discussion of the one-adjustment principle. It was not until January, 1927, that Massachusetts attempted to demonstrate before the Conference its conclusions with regard to the question. In that demonstration, it was inferred that various authorities, including the Society of Automotive Engineers, the Illuminating Engineering Society and the Bureau of Standards, favor single adjustment for double-filament head-lamps, but an analysis of their respective positions seems to support this contention only to the extent of simplification of adjustment insofar as that is compatible with the results to be obtained.

The S.A.E., according to our files, has merely gone on record as favoring the simplification of head-lamp adjustment, and up to this time has, in my opinion, very wisely disposed of the question only by recommending, as standard practice, *"that the head-lamps should be designed so that not more than one focusing-adjustment should be necessary."*

The 1926 report of the Committee on Motor-Vehicle Lighting of the Illuminating Engineering Society, of which Committee several of the opponents of double adjustment are active members, includes the following:

> One of the most difficult factors in improving conditions is the maintenance of equipment in satisfactory operating condition, and this improvement will eventually be furthered most effectively by simplification of all adjustments. Some two-filament devices are sensitive to certain variations in the position of the light-sources and, *when such variations are present, the desired results cannot be obtained with only one focusing-adjustment.*

The files of the Pennsylvania Bureau of Motor-Vehicles contain considerable correspondence with the Bureau of Standards; and in July, 1926, I, accompanied by Inspectors Bunting of Pennsylvania and Shanley of New Jersey, made a special visit to its laboratories in the City of Washington in an effort to obtain, if possible, a definite expression in this regard. We took with us incandescent lamps and head-lamps of various types; but, after a full day of tests, were able only to elicit the information that, while the Bureau favored the simplification of adjustments on all head-lamps, with which we are in hearty accord, *it was obvious that two adjustments would be necessary on some types of double-filament head-lamp.*

These tests were made prior to the Conference demonstration previously mentioned, so that we might have the benefit of the experience of the Bureau of Standards for that demonstration; but at that time, and since then, in spite of constant efforts in many directions, we have been unable to obtain any authoritative information as to what type of two-filament head-lamp should have two adjustments and what type should have only one. Our tests fail to show any appreciable difference in performance of the two types when subjected to the same tests (see Table 2).

Certainly the proponents of multiple adjustment cannot be accused of attempting to dispose of this troublesome question by snap judgment. It is to be doubted whether any other agency has given it as much real serious consideration from an impartial viewpoint, else why should it be necessary for some of the advocates of single adjustment to resort to all sorts of questionable pressure and accusation to gain an end which, by their own disagreement, they virtually admit is not the desired one?

If, as has been suggested, the object is to disrupt the Eastern Conference of Motor-Vehicle Administrators, I am not predicting what will follow, but am merely suggesting that you consider whether any benefit would accrue to head-lamp manufacturers. Weigh your present imagined troubles against the actual difficulties you had before the Conference was organized.

Alignment of Head-Lamp Fronts

Exception has been taken to the data assembled by the State of Pennsylvania that the second focusing-mechanism is used as an argument to align the fronts of the head-lamps for the sake of appearance. While that is a much-desired condition, if these data are correctly analyzed it will be found that they go into the question much deeper than that. However, even if this were the reason, and it is a justifiable one, one of the advocates of single adjustment has been urging for some years that the head-lamp fronts be set perpendicular to the axis of the car, and it is possible that certain engineers will recall the occasion when they were required to put a 4-deg. tilt in their reflectors to keep their head-lamp fronts straight. Ask any service or factory mechanic if he is permitted to send cars out of the shops with head-lamps tilted at various angles, which the opponents of double adjustment admit is necessary, even in some cases where the incandescent lamps are turned over.

Two Adjustments Supported Within the Industry

It has been alleged that the Monogram Lens Corporation is the original proponent of double focusing, whereas our researches in the Patent Office show many patents granted on this principle, long antedating its use by that company. Curiously enough, one such patent was granted to an engineer connectd with one of the companies which vigorously objected to the Conference ruling, although none was found in the name of the Monogram Lens Corporation or of its officers. To say, as has been charged, that the Monogram Lens Corporation is the only known supporter of this principle, except its advocates who are members of the Eastern Conference of Motor-Vehicle Administrators, is a broad statement and, by inference, might be taken to imply that some members of the Conference are given to partiality or worse. I defy anyone to show that Pennsylvania and New Jersey, at least, have not held paramount the interests of the motorists.

The sole concern of their representatives apparently has been to assure to their citizens the benefits to be derived from reducing the present hazards and menaces of night-driving conditions, which I am sure you will agree with me are many and varied. Undoubtedly, many of these annoyances can and will be eliminated by effective road-enforcement measures, but one of the chief functions of an administrative department is to endeavor to catch them at their source, which in this case means attempting to have the head-lamp manufacturer build head-lamps as nearly perfect as possible or at least commensurate with the expense and effort devoted to other features of automobiles.

Aside from the engineers connected with such organizations as are represented among those makes of car using double-filament head-lamps with two adjustments, it is interesting to note the following excerpt from a letter addressed to Registrar Eynon of Pennsylvania under date of Nov. 12, 1925, by one who, in the light of his experience of the last several years as one of the foremost manufacturers of automobile head-lamps, may also be regarded as a competent authority, particularly since his company, I believe, constructs and markets all three of the two-filament devices now on the approved list, under licenses from the holders of certificates of approval. I refer to W. F. Anklam, president of the C. M. Hall Lamp Co., who writes as follows:

> Responding to your communication of the 9th instant, letter reference O. R. 880, paragraph one, some 3 or 4 weeks ago Mr. Staples, of the Macbeth-Evans Glass Co., in company with the writer, interviewed R. N. Falge, commercial engineer of the National Lamp Works of the General Electric Co., Nela Park, Cleveland, when the subject of an axial and vertical-focus adjustment came up in relation to the Hall-Macbeth head-lamp that was to be submitted to the Commissioners of the Eastern Conference. Mr. Falge distinctly stated that an axial adjustment would be sufficient, which statement was made on the methods employed by them in the manufacture of bulbs and the extensive experience that they have had in light projection. *In making this reference, it is not our intention to convey to you the idea that we approve of his interpretation and instead our ideas are in ac-*

cord with yours, in that an axial and vertical-focus adjustment should be provided where two-filament bulbs are a part of the headlight unit.

Since this question has been raised that we have no competent opinion on our side, I must also draw your attention to the following quotation from a paper presented at the annual convention of the Illuminating Engineering Society, Sept. 15 to 18, 1925, by R. N. Falge, formerly with the National Lamp Works of the General Electric Co. and now a member of the staff of the General Motors Corporation Research Laboratories, who is generally recognized as the developer of the two-filament incandescent lamp and is widely known as a competent illuminating engineer:

> Although the tilt between the beams is not materially affected by small variations in the distance of the upper filament above the focus of the reflector, it is very sensitive to the positioning of the lower filament. *In order to ensure proper positioning of the lower filament with respect to the focus of the reflector, it is necessary to provide a focusing screw for vertical adjustment to compensate for variations in bulbs and head-lamp assembly.*

As further evidence of Mr. Falge's opinion that commercial variations can be met only by using the vertical adjustment, I quote from a letter which he addressed under date of May 5, 1926, to George C. Cousins, assistant laboratory engineer, Hydraulic Power Co., Toronto, Ont., Canada. Bear in mind that this letter was written after the April, 1926, meeting of the Eastern Conference, at which the requirement of two adjustments was recommended, and dates approximately 8 months subsequent to his paper previously referred to. In spite of the known inaccuracies, it is evident that little or no improvement in construction or inspection had been made in that time, because Mr. Falge says, in part:

> The difficulty arises when commercial variations in incandescent lamps, sockets and reflectors are such that the filaments are located a small distance above or below their proper position. *The vertical focusing adjustment is provided to correct such variations. . . .* The extent of commercial inaccuracies is fairly well established. The acceptable beam-variation is, of course, a matter of judgment. In view of the fact, however, that variations of 4/64 in. above and below the focal point result, with ordinary equipment, in a change from a design tilt of say 2 deg. between beams to tilts of 0 and 4 deg. respectively, this variation, in our opinion, is hardly acceptable. . . . *It is supposed that at some time in the future variations will be reduced to the point where even the ordinary equipment will perform satisfactorily without the additional focusing-adjustment.*

At another place in this same communication concern is expressed lest the motorist might become confused and find it difficult to focus his lamps because of the additional adjustment. Surely, lamp manufacturers are going far afield when they not only attempt to compel administrators to accept whatever lamps they submit but then point out that the administrators ought to follow the line of least resistance in the enforcement of the law. The altruistic opinions of the lamp manufacturers, as revealed in their controversies with the Eastern Conference, are laughable.

Summary

In summing up, it seems that the following points stand out:

(1) Manufacturers of motor-cars, head-lamps, and incandescent lamps are still trying to fool the motoring public with cheap and inefficient head-lamps, and by the methods employed in this particular controversy are evidently bent on disorganizing an association which they must admit has been of considerable assistance and benefit to them

(2) Double-filament head-lamps and incandescent lamps as now designed, constructed and distributed have not sufficiently justified themselves to the public or to enforcement authorities, to the extent that they may be used without some restrictions to assure their performance in accordance with the claims made for them

(3) Insensitive head-lamps cannot become a reality until head-lamp manufacturers give more consideration to the motorist and less to the purchasing agent of the motor-car company. A good pair of head-lamps cannot be made and sold for $1.87 per pair

(4) Present adjustment instructions, at best, are difficult of comprehension but are not made any more so by the introduction of an additional adjustment on two-filament head-lamps

(5) The vertical adjustment may be used for aiming the beam without serious results, and recent developments indicate that it may displace the inefficient and troublesome S.A.E. mounting for this purpose. Therefore, future development has not been retarded

(6) The requirement of two adjustments is not inconsistent nor unjust, in view of the research data compiled by its proponents and the very evident indecision and disagreement among engineering authorities and its opponents

(7) In view of the foregoing, it is significant that the chief arguments advanced by the opponents of double adjustment have been reduced to two, neither of them valid from either a practical or a technical viewpoint: It will cost perhaps 5 or 10 cents more per head-lamp and the motorist will not understand its use

(8) If we are to maintain safety on our highways, the question of price should not, and will not, be allowed to enter the discussion, and the question of educating the motorist in the use of his equipment is one which might well be left with the enforcement authorities, since, until this particular question arose, the head-lamp and motor-car manufacturers certainly passed it along to anyone who wished to assume the burden.

Conclusions

The argument advanced against a double-focusing mechanism by lamp manufacturers, that satisfactory instructions for use cannot be drawn up, is a ridiculous contention. The only argument with any validity against double focusing is that head-lamps so equipped may be maladjusted by the car operator. Such a condition is the concern of the law-enforcing authorities and not that of the lamp manufacturers, who have always evidenced little or no concern for motor-vehicle-law enforcement. As between a single-focusing head-lamp that cannot compensate for commercial variations in incandescent lamps and a double-focusing one that can, but may be maladjusted, give us the latter. We will take care of the adjusting.

It seems strange indeed that, with the advent of the two-filament lamp, the lamp manufacturers should suddenly become so altruistic and solicitous about the motoring public, since prior to that time the sum-total of

the lamp industry's concern for the lamp user was almost exactly zero. The head-lamp manufacturers in a very careless and hodge-podge fashion assembled the head-lamps and shipped them to the car manufacturers, who attached them to the cars, pausing only long enough to see that both head-lamp fronts were in the same vertical plane. We are not so sure in our opinion as to what prompted this avowed sudden solicitude for the car user on the part of the head-lamp manufacturer, but we do know that it must of necessity be just a side-issue, while with the enforcement authorities the cares and troubles of the car user always have been and always will be their entire credo.

I believe I speak for the entire membership of the Eastern Conference in this respect. There are some States wherein the collection of revenues is regarded as the paramount duty of the Motor-Vehicle Department, but in the States and Provinces that have membership in the Eastern Conference the great complex problem is the conservation of human life, and the question of revenue, a bookkeeping problem at most, is secondary.

At the advent of the two-filament lamps I was skeptical as to the length of time that might ensue before the use of such lamps would be abolished. From information gathered, however, it seems that the two-filament lamps may become the lamps of the immediate future. Let me, therefore, make this prophecy:

> If an ideal head-lamp with no adjustments ever is designed, and in the interim we have to struggle with one adjustment, that one adjustment will be a *vertical adjustment.*

[4] M.S.A.E.—Physicist and chief of division of heat and power, Bureau of Standards, City of Washington.

THE DISCUSSION

CHAIRMAN H. C. DICKINSON[4]:—Probably there is no accessory or part of a motor-car which would be so universally condemned by the average user as the head-lighting equipment. I believe that if 100 users of cars in the Country were asked whether they think head-lighting is good or not, 90 per cent of them would say that they think headlighting is not nearly so good as it should be. Probably no such percentage would make such a remark about any other feature of the machine.

A large amount of work was done some years ago toward the development of a satisfactory type of regulation or legal control of electric headlighting. Since the work was done on which the existing regulations are based, there have been radical changes in the conditions of road traffic. Probably there are 10 times as many cars on the highways at night, perhaps 20 or 30 times as many, as there were when existing regulations were developed. The position of the driver and passengers is perhaps 12 in. lower than it was at that time, and the springs are much more flexible than they were then, the result being that the margin of safety between troublesome glare and road illumination has been narrowed, and, everything taken into consideration, the problem has become much more serious.

In addition, developments have pointed more and more toward possibilities for the more convenient use of double-beam equipment of various kinds, and the ingenuity of head-lamp designers has pointed the way to a large number of possible improvements. There are three simple possibilities in the way of maintaining the focusing adjustment of head-lamps; these are with two adjustments, with one adjustment and with no adjust-

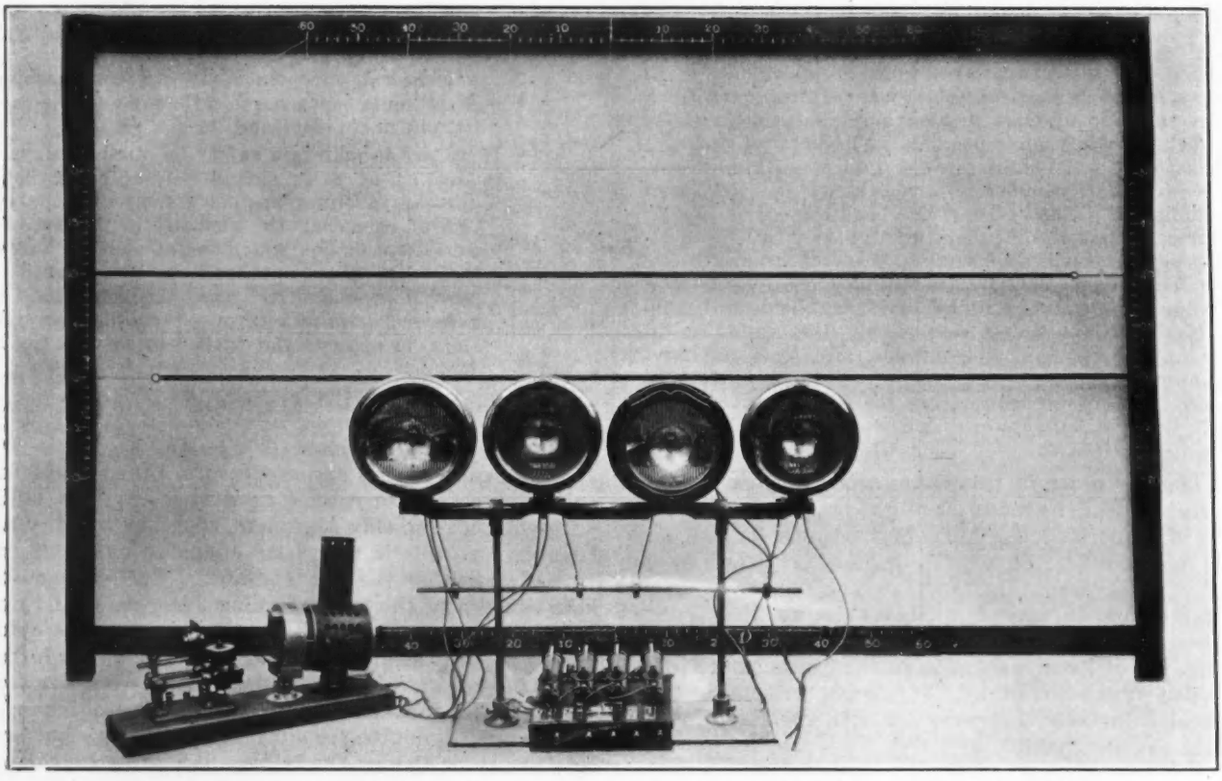


FIG. 1—DEMONSTRATION APPARATUS USED AT THE HEADLIGHTING SESSION AT THE SUMMER MEETING

One Pair of Single-Focusing and One Pair of Double-Focusing Head-Lamps Are Mounted on the Test-Bar and Operated with the Switches Below. One of Each Pair Is a Regular Production Head-Lamp Provided with the Usual Focusing Mechanism, While the Other Has a Laboratory Attachment for Moving the Incandescent Lamp by Known Amounts in Any Direction To Demonstrate the Effect of Inaccurately Placed Filaments. In Left Foreground Is a Stereopticon for Projecting Images of Lamps and Their Filaments on the Standard Focusing-Screen in the Background, upon Which Was Thrown the Light from the Head-Lamps To Show the Light Distribution from the Head-Lamps

ment, and there is, of course, a great deal of room for difference of opinion. In view of the nature of the subject, the Society has asked R. N. Falge, chairman of the S.A.E. Sub-Committee on Headlighting, to bring some demonstration equipment for use in illustrating some of the points brought out in the paper and discussion. He will describe the apparatus briefly.

R. N. FALGE[5]:—Five head-lamps have been provided for demonstration purposes. One is a head-lamp equipped with the fixed-focus socket which will be described by C. C. Bohner. Two of the head-lamps on the test-bar, shown in Fig. 1, are of the single-focusing type. One of these is from regular production and is provided with the single-focusing mechanism ordinarily used with this device. The other is provided with a laboratory attachment for moving the incandescent lamp by known amounts in any direction to demonstrate the effect of inaccurately placed filaments. The other pair of head-lamps on the test bar is of the double-focusing type. One of these is a production lamp equipped with the regular double-focusing mechanism. The other has a universal focusing-mechanism similar to that previously mentioned. The stereopticon in the left foreground is for projecting the filaments in an incandescent-lamp on the screen so that you can see the defects before the lamp is tried in the head-lamps.

The Research Department of the Society sent out a general letter some time before this meeting requesting that members of the Society bring with them any incandescent lamps they regarded defective as purchased on the open market. Two such lots of lamps have been turned in. If there are any more, please bring them forward so that we can see how they perform in the head-lamps when the matter comes up in discussion.

CHAIRMAN DICKINSON:—It is only our best friends who tell us what is wrong with us. Others usually tell somebody else. I am sure that the car manufacturers, the head-lamp manufacturers, the incandescent-lamp manufacturers and others here will welcome Mr. Matthews as one of our best friends.

RESULTS OF A MASSACHUSETTS SURVEY

A. W. DEVINE[6]:—If the information given in my paper[7] were all that was available, engineers could predict the results in service with either single or double-focusing equipment. But focusing is not something about which we have to guess. It is susceptible of engineering analysis, as is any similar engineering problem.

Fortunately, as I indicated in the paper, both types have been in service for considerable periods, and we can ascertain whether the additional vertical-focusing mechanism has improved conditions or otherwise. For example, Tables 4 and 5 show the results of a survey made by six inspectors attached to the Massachusetts Registry of Motor-Vehicles on 625 cars equipped with two-filament tilting-beam head-lamps of both the single and the double-focusing types in the cities of Boston, Lynn and New Bedford from May 6 to 14, 1927.

The results from all of the 625 cars are included in Table 4, in which the summary of the data for single and for double-focusing-mechanism head-lamps is given in two ways; above, by different approved head-lamps; below, in condensed form. There were 456 cars with single-focusing tilting-beam head-lamps, and 169 cars with

TABLE 4—SUMMARY OF DATA ON TWO-FILAMENT TILTING-BEAM HEAD-LAMPS INSPECTED IN BOSTON, LYNN AND NEW BEDFORD, MASS., MAY 6 TO 14, 1927

Head-lamp	Focusing Adjustments	Focused		Not Focused One- or Two-Filament Lamps, Including Two-Filament Lamps with No Tilt		One Set of Filaments Focused One Set Out of Focus, Pairs	All Filaments Out of Focus, Pairs	Total Head-lamps Inspected, Pairs
		Two-Filament Lamps, Pairs	One-Filament Lamps, Pairs	Pairs	Per Cent of Total			
A	1	6	0	1	14.3	0	0	7
B	1	1	0	0	0.0	0	0	1
C	1	378	16	52	11.6	1	1	448
D	2	51	5	34	37.7	0	0	90
E	2	49	1	29	36.7	0	0	79
Totals and	Per Cent	485	22	116	18.6	1	1	625
Totals of Single and Double-Adjustment Head-Lamps								
.....	1	385	16	53	11.6	1	1	456
.....	2	100	6	63	37.3	0	0	169
Totals and	Per Cent	485	22	116	18.6	1	1	625

double-focusing head-lamps. Of the former, only 11.6 per cent were not focused, while 37.3 per cent of the latter were not focused, including in this classification those pairs of head-lamps which had no tilt or a negative tilt More double-focusing head-lamps than single-focusing head-lamps were not focused.

Of the foregoing 625 cars, as shown in Table 5, 443 had head-lamps which were classed as focused, judging by the appearance of the upper beam only, and these were so tabulated by the inspectors that they could be classified separately under three headings: (*a*) those with definite cut-off and downward tilt, (*b*) those with no tilt or a negative tilt, and (*c*) others with an indefinite cut-off for the upper beam. Of the 443 cars, 308 had single-focusing head-lamps and 135 had double-focusing head-lamps.

Note that in this second summary of data 99 per cent of the focused single-adjustment head-lamps were entirely satisfactory in performance, and only 1 per cent had an indefinite cut-off for the upper beam. On the other hand, only about 64 per cent of the focused double-

TABLE 5—SUMMARY OF DATA IN TABLE 4 WITH 130 CARS EXCLUDED BECAUSE REPORTS OF MAY 6 AND 7 TABULATED AS "NOT FOCUSED" HEAD-LAMPS HAVING A BEAM WITH ZERO OR NEGATIVE TILT

Head-Lamp	Focusing Adjustments	Focused							Tilt at 25 Ft., In.		
		Two-Filament Lamps[8], Total Pairs	Definite Tilt and Cut-off		Zero or Negative Tilt		Indefinite Cut-off, Upper Beam		Minimum	Maximum	Average
			Pairs	Per Cent	Pairs	Per Cent	Pairs	Per Cent			
A	1	6	6	100.0	0	0.0	0	0.0	12	18	14.5
B	1	1	1	100.0	0	0.0	0	0.0	15	15	15.0
C	1	301	298	99.0	0	0.0	3	1.0	8	20	13.6
D	2	70	48	68.6	14	20.0	8	11.4	−5	18	9.5
E	2	65	38	58.5	12	18.5	15	23.0	0	20	10.9
Totals and		443	391	88.2	26	5.9	26	5.9	−5	20	12.7
Per	Cent										
Totals of Single and Double-Adjustment Head-Lamps											
...	1	308	305	99.0	0	0.0	3	1.0	8	20	13.6
...	2	135	86	63.7	26	19.3	23	17.0	−5	20	10.2
Totals and		443	391	88.2	26	5.9	26	5.9	−5	20	12.7
Per	Cent										

[5] M.S.A.E.—Head of lighting section, General Motors Corporation Research Laboratories, Detroit.

[6] M.S.A.E.—Automotive equipment engineer, Registry of Motor-Vehicles, Commonwealth of Massachusetts, Boston.

[7] See THE JOURNAL, June, 1927, p. 727.

[8] Head-lamps classed as focused if the beam was well defined to give results that may be expected from head-lamps adjusted by moderately capable adjusters. Determination from appearance of upper beam only.

adjustment head-lamps were entirely satisfactory, while about 36 per cent had either no tilt, a negative tilt or an indefinite cut-off for the upper beam.

Now look at the tabulation of the amount of tilt between upper and lower beams. The single-adjustment head-lamps show variations of 12 in. in the amount of tilt; that is, from 8 in. to 20 in. The double-adjustment head-lamps show variations of 25 in., more than twice as much, and the range was from a downward tilt of 20 in. to an *upward* tilt of 5 in.

Just a word about price. It might seem that cost could be reduced by the elimination of one focusing-adjustment from a double-adjustment head-lamp, but, even though that were true, it has no bearing on the principle involved. One might just as well say that a manufacturer is cutting cost by not putting an ornamental Billiken on top of each head-lamp. It would be as applicable to the subject under discussion. The installation of a second focusing-adjustment on a head-lamp is like the case of the man who has one black eye and feels sensitive about his appearance. To cure that condition, he asks a friend to black the other one.

Adapter Ring Proposed for Fixed Focus

C. C. Bohner[9]:—I am sure you are in the frame of mind to hear about fixed-focus, or no-adjustment, lamps. Much has been said and written on the subject of focusing and aiming head-lamps within the last 8 years. During this time three popular methods have been suggested and fostered by various followings. These are single adjustment, which corrects for horizontal inaccuracies; double adjustment, which corrects for both horizontal and vertical inaccuracies; and no adjustment at all. In the last case the thought is that manufacturing deviations will be less troublesome than the corrections attempted by the average motorist.

A number of fixed-focus units are in use. The light sources in these equipments are nearer the focal area of the reflectors than in 80 per cent of the accepted adjustable types on the road today regardless of whether they are of the single, double or universal type of adjustment. In a recent investigation, before compiling a set of focusing instructions including focusing charts, we found the average condition, even in the better-regulated communities, to leave a great deal to be desired. In making an actual check of cars on the road, without selection for type of equipment, simply taking the cars as they came along, it was found that 70 per cent of the focusing and aiming was very bad. Only 2 cars out of 50 were found to be passable under generally accepted standards. A great deal of this is due to the fact that most bulbs are changed during daylight at a place not satisfactory for focusing or adjusting, which is left to the owner, who does not have the necessary information or equipment to do the work properly.

During our investigation we were much impressed with the need of simplicity in instructions. In talking to one car owner, above average intelligence, we found he had tightened the focusing screw to stop a rattle inside the head-lamp. He was much surprised to learn that it is possible to change the relation of the light source to the reflector with this screw.

The time is right to begin the use of a fixed-focus receptacle, as a review of manufacturing processes will indicate. As recently as 4 years ago it would not have been reasonable to depend upon a high percentage of the bulbs on the market to come within fixed-focus limits, but the rapid trend toward automatic-machine production which has greatly increased the ability to duplicate accurately has created a change in the situation. Investigations by State authorities, which have been referred to in papers read before this Society, have definitely proved that the present product is much more accurately manufactured than was the case a few years ago. This improvement has been made in spite of the fact that the incandescent lamp is held by the base while measurements are being made.

Basing Produces Filament Inaccuracies

One of the most discouraging features in the control of light-source position has been the base, which acts as a terminal and locating device for the bulb in the socket. This base varies in diameter 0.008 in.; it varies 2/64 in. from the open end of the shell to the locating-pin; it is larger at the contact end than at the open end; and it is very rarely cylindrical. Because of these inaccuracies, it is difficult to place it on a bulb so that its center line is parallel to the center line of the bulb, as there is no satisfactory mechanical means for so doing. Examination of a number of lamp rejects which were thrown out because the light source was found to be outside of the 3/64-in. specification shows that in practically every instance the light source had been accurately positioned with regard to the bulb center-lines but was thrown off in the process of basing. Add to these inaccuracies the possibilities for deviation in the sleeves, the sockets and the focusing mechanism. The sockets, in particular, are subjected to more or less variation due to the offsetting or upsetting which occurs in closing the open end of the conventional compensating type.

During the bulb-manufacturing process when the filament or light source is being located, the bulb is held in a fixture so that the light source is always positioned or located with a definite relation to fixed reference areas or rings. We suggest the use of a fixed ring to be secured to the reflector without adjustment; this fixed ring to be the same size and shape as the reference ring used in the manufacturing process in locating the light source within the bulb. This will eliminate all of the inaccuracies in base manufacture as well as most of the inaccuracies which occur during the lamp-fabricating process. This would be no hardship for the bulb manufacturers, as it is necessary now to design bulbs to a fixed ring which is usually the average diameter of the base. This ring would be moved slightly toward the maximum diameter of the bulb and, instead of being 0.6000 in., would be approximately 0.6875 in. in diameter. The shape of the bulb could be varied in any way desired so long as the locating ring remains constant.

The method suggested would make it possible for an owner to release a burned-out lamp from this fixed ring by simply pressing forward a plunger and removing the bulb. When a new lamp was installed his only consideration would be to release the plunger, which would automatically seat the bulb on this ring, the position of which would be predetermined and fixed. Vibration would only tend to seat the bulb better in its proper location.

Cement Withstands 80-Lb. Pull

The question will naturally arise as to the holding quality of the cement securing the base to the bulb. Tests have shown that 80 lb. can be applied before any lamp not over 2 years of age can be parted; that is, there will be no breaking down of this cement with less

[9] M.S.A.E.—President and general manager, Tung-Sol Lamp Works, Newark, N. J.

than 80-lb. pulling stress. In 80 per cent of the instances the pins are torn from the shell or the glass in the bulb is crushed or broken before the cement lets go. The spring pressure required to hold the bulb in position without excessive vibration is in the neighborhood of 4½ lb., which is practically negligible. An occasional loose base is found today in head-lamp sockets. The cause in most instances is a combination of weather and vibration rather than faulty material or processes.

Objection may be raised to the larger receptacle that may be necessary inside of the reflector. There is no objection on this account because of the loss of light directed to the reflector or because of the reflecting surface of the receptacle, which can be finished with a low-reflecting surface.

There would be no difficulty in servicing the first cars equipped with these adapters, as any bulb that is satisfactory for installation in this ring would also be satisfactory for installation in the present conventional socket. There should be no added cost in the manufacture of either the bulb or the lamp-and-reflector assembly.

This suggestion is not offered as a compromise between single and double adjustment; it is brought forward at this time because we believe that the development of both reflectors and bulbs has been advanced to the point where it is now advisable to combine the two without further adjustment. Night-driving conditions will thereby be vastly improved and dangers caused by lack of focusing will be greatly minimized. Law enforcement should be greatly aided, as an observer at the side of the road could quickly determine the cause of glare without the use of a screen.

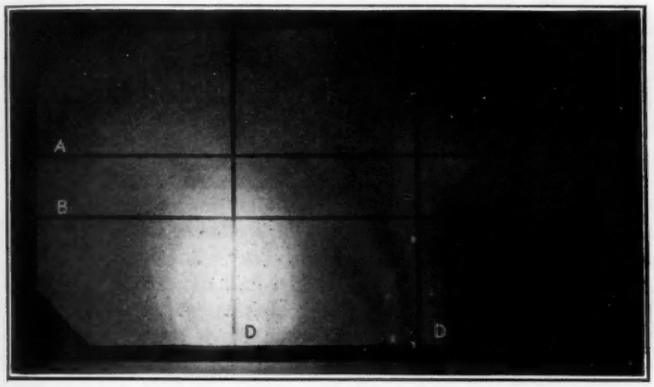


FIG. 2—LIGHT-SPOT WITH UPPER BEAM OF LEFT HEAD-LAMP FOCUSED AND AIMED

Top Center of Light-Spot Should Be at the Intersection of Lines *B* and *D*. Greatest Intensity of the Beam Should Be Near the Bottom of the Spot, not at the Center

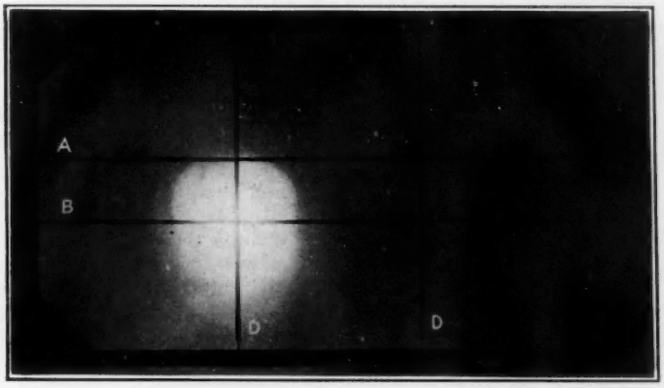


FIG. 3—LIGHT-SPOT WITH LOWER BEAM OF LEFT HEAD-LAMP FOCUSED AND AIMED

Center Top of the Light-Spot Should Be at the Intersection of Lines *A* and *D*. Greatest Intensity of the Beam Should Be Near the Bottom of the Spot, not at the Center

CHAIRMAN DICKINSON:—Mr. Bohner has certainly presented an interesting suggestion. Would Mr. Matthews like to make any further remarks in the light of what has been said by the other speakers?

W. W. MATTHEWS:—I have nothing to add except that I want to assure Mr. Devine that any remarks I made were only for the purpose of presenting some facts with which I thought the Society was not entirely familiar. I think perhaps both Mr. Devine's paper[10] and my paper have tended to show that none of the head-lamps we have on the market now is very good.

[10] See THE JOURNAL, June, 1927, p. 727.
[11] M.S.A.E.—Consulting engineer, New York City.
[12] Jun. S.A.E.—Mechanical engineer, Tung-Sol Lamp Works, Newark, N. J.

DIFFICULTY OF DOUBLE ADJUSTING DEMONSTRATED

CHAIRMAN DICKINSON:—The Program Committee suggested that it might be of interest to ask some volunteer from the audience, preferably one who is not particularly familiar with headlight matters, to show us the actual operation of adjusting single and double-adjustment head-lamps. Therefore I have been asked to invite someone to volunteer for the purpose. Is anyone willing?

CHARLES M. MANLY[11]:—Mr. Veal, manager of the Research Department of the Society, told me this evening that I had been selected as one totally ignorant of headlight adjustment to see if I could understand how to adjust one. I told him I would help out if no one else offered.

CHAIRMAN DICKINSON:—Mr. Falge having brought the equipment here, I shall ask him to explain what is proposed.

MR. FALGE:—In making these demonstrations we had planned to provide the adjuster with the printed instructions usually furnished with each type of head-lamp. There seems to be some question regarding the practicability of the instructions issued on the double-focusing head-lamp. If you prefer to give the instructions, Mr. Matthews, you may do so.

MR. MATTHEWS:—Suppose you have him read those.

DONALD A. HARPER[12]:—These instructions, as issued by the head-lamp manufacturer, are as follows:

> Light the upper filaments of both bulbs and cover right head-lamp to obstruct light, then remove the door of the left head-lamp and see that the "fog cap" is properly placed on the bulb.
>
> Now turn upper focusing-screw until light spot on the screen is of the smallest possible diameter; that is, that point where a turn of the screw either to the right or left will increase the size of the spot.
>
> Loosen the nut on the universal lamp-mounting and aim the head-lamp so that the center top of this beam is at the intersection of lines *B* and *D* as in Fig. 2; then tighten the nut to hold head-lamp firmly in this position. Next, turn lighting switch so that the lower filament is lighted and turn lower tilt-screw to the right or left until the center top of this beam is at the intersection of lines *A* and *D* as in Fig. 3. This beam should then be of approximately the same proportionate size as in Fig. 3, and the highest intensity in the beam should be near the top, not center, of the spot. If the upper filament is now lighted, the lower beam should appear as in Fig. 2, and be of the same propor-

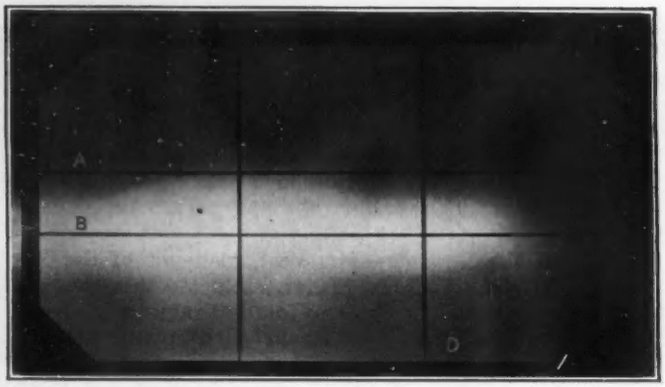


FIG. 4—UPPER PATTERN OF LIGHT FROM LEFT HEAD-LAMP
With Lens and Door Installed, the Upper Beam of Light Should Cut Off at Line *A*, and Center of the Pattern Should Be Along Line *B*

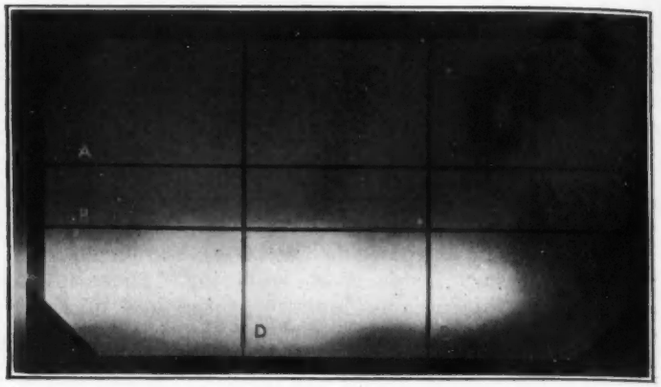


FIG. 5—LOWER PATTERN OF LIGHT FROM LEFT HEAD-LAMP
Cut-Off of the Lower Beam Should Be at Line *B*, and the Vertical Center Should Be at Line *D*, to the Left, When Lens and Door Are in Place

tionate size, and the highest intensity should be near the bottom, not center, of the spot.

Install lenses and door, being sure that the cylindrical flutes in the lens are vertical. The upper pattern of the light on the screen should then appear as in Fig. 4, and the lower pattern of light should be as in Fig. 5.

Cover left head-lamp and repeat this adjustment on right head-lamp; then upper patterns of light from both head-lamps should appear on screen as in Fig. 6, and lower patterns should appear as in Fig. 7.

If beams from head-lamps do not rise and lower together, turn out lights, remove contact plug from lamp shell, then turn half way over and replace.

If head-lamps were correctly adjusted before replacing bulb, it is not necessary to change the adjustment or "aim" of the complete head-lamp.

Remove old bulb from reflector and take off "fog cap", then put cap on new bulb so that when installed in reflector it will be positioned at the top of bulb. Now turn upper focusing-screw to right or left until beam from lower filament, which projects upper beam on screen, is of the smallest possible diameter. Next turn tilt-screw to the left or right until the top of the upper beam from this lamp is the same height as the upper beam from the other head-lamp.

[Less than 1 min. was required to put the single-focusing head-lamp into almost perfect adjustment. But, after spending some time in attempting to follow the printed instructions applying to the double-focusing head-lamp, Mr. Manly abandoned his efforts to focus it properly.]

NEED UNIFORM REQUIREMENTS AND TESTS

W. D'ARCY RYAN[13]:—That Mr. Devine and Mr. Matthews have honest differences of opinion is not at all surprising. The fact that they and other members of the Eastern Conference have been able to get together and agree upon so many important points in the headlighting field is rather marvelous considering the devices they have had to work with. The papers read tonight and the demonstration we are now having convince me more than ever that we must do away entirely with focal adjustment. Until we do this, we shall never get very far in correcting the headlight troubles of today.

Yesterday I received a very elaborate publication describing one of the principal and most expensive automobiles built in this Country. Considerable space was given to extolling devices on the car which could be eliminated without introducing any real element of danger, yet the head-lamps were absolutely ignored. We cannot assume that the automobile manufacturer does not appreciate the importance of safety considerations in good headlighting, and in this particular case price was not a factor of moment. It goes further back than that. The trouble today is that a manufacturer cannot put on

[13] M.S.A.E.—Director of the illuminating engineering laboratory, General Electric Co.; president, Ryan-Lite International Corporation, Schenectady, N. Y.

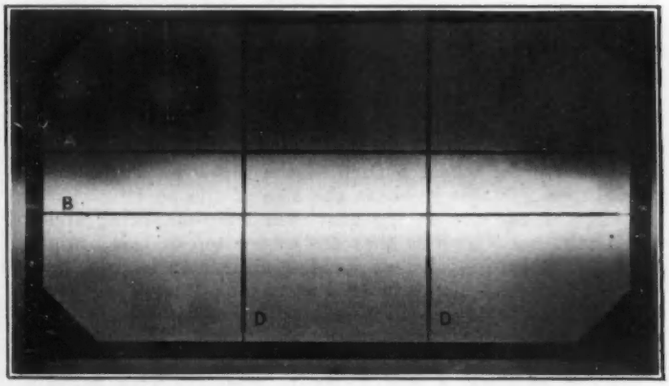


FIG. 6—PATTERN OF UPPER BEAMS FROM BOTH HEAD-LAMPS
When the Right-Hand Head-Lamp Has Been Focused and Aimed To Obtain on the Right-Hand Portion of the Screen a Pattern Corresponding to That on the Left Portion in Fig. 4, the Upper Beams from Both Head-Lamps Should Give a Light Distribution as Above

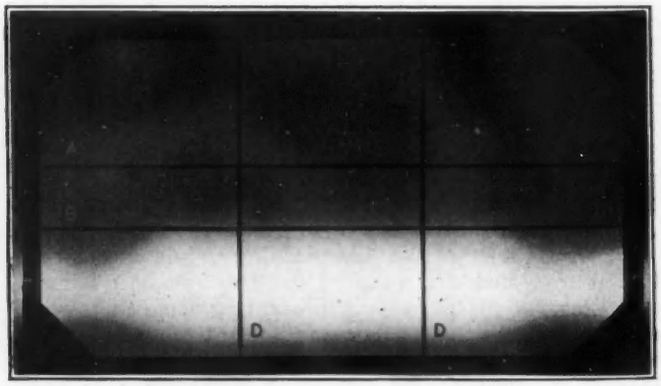


FIG. 7—PATTERN OF LOWER BEAMS FROM BOTH HEAD-LAMPS
With the Lower Beams of Both Head-Lamps Properly Focused and Aimed Separately, the Light Distribution of the Two Beams Should Show the Top Cut-Off at Line *B*, and the Intensity of the Light Should Be Equal on the Left and Right Portions of the Screen

a car a lamp that is not approved in every State. Here is the difficulty: If the Eastern Conference could extend its sphere of activity to reach all the States we should have one tribunal to go to instead of having to go all over the United States having approvals made here, there and everywhere under different specifications.

The Eastern Conference, with the exception of one State, will accept tests made by the Electrical Testing Laboratory in New York City. This one exception requires tests by the Bureau of Standards. Texas will not accept anything but tests from the University of Texas. California will not accept anything except from the University of California. Oregon will not accept anything but a Bureau of Standards test. So we have all these different places to make tests, and the specifications differ. The Eastern Conference accepts the Illuminating Engineering Society specifications, which require a minimum of 800 and a maximum of 2400 cp. at the *C* point on the I. E. S. Standard screen. California requires a minimum of 500 and a maximum 1500 cp. So the situation is most difficult. This is possibly why some of the manufacturers are afraid to say anything about head-lamps in their literature.

A great deal undoubtedly will be accomplished this year. I believe this meeting will do much good. We are all thinking more and more about the headlighting problem. My belief is that we must eliminate the focusing and make other advances. If we have one tribunal to go to, it will vastly improve the situation. Some regard the Eastern Conference as an obstacle to progress; on the contrary, it has saved more lives than one can imagine. We are now disturbed by the great number of automobile casualties, many of which occur at night, but had it not been for Conference control in handling the headlighting problem, under the most difficult conditions with bad apparatus, casualties undoubtedly would have been much more numerous. It is not that we need less regulation; we need more, but it should be unified and consolidated in such a way that it is not split up all over the United States.

Defective Lamps Demonstrated in Single and Double-Adjustment Head-Lamps

Chairman Dickinson:—As some of you may think that the demonstration we have seen is not a fair test of the two-filament adjustment, I shall ask if Mr. Matthews is willing to put the two-filament head-lamp in adjustment without any instruction, because he is thoroughly familiar with it.

Mr. Matthews:—Will Mr. Falge insert these bulbs in the single-adjustment lamps? They are not anything special; I have no idea what will happen.

[The four incandescent lamps were inserted successively in the production single-focusing head-lamp, and careful observation showed that neither the light pattern nor the aim was exactly the same in all cases. Mr. Matthews called attention to this variation and pointed out that it could be avoided through the use of the double adjustment. Mr. Falge expressed the opinion that the question was not whether the beam patterns were all alike but whether it was possible to provide satisfactory road-lighting over the range of variation encountered. It was then suggested that more uniform patterns might result if the lamps were tried both ways in the head-lamp. In reversing them it was apparent that the socket was accurately located in the reflector so that the effect was merely to transfer the inaccuracy from one side of the reflector axis to the other. Mr. Falge pointed out that a noticeable improvement could be expected only when inaccuracies were present in both the incandescent lamp and the socket. For one lamp position the errors would be additive; for example, if the filament was 3/64 in. high in the lamp and the socket was 2/64 in. high in the reflector, the total error of the filament with respect to the reflector would be 5/64 in. If, in this case, the lamp were reversed in the socket, the errors would be subtractive and the net error would be reduced to but 1/64 in. Serious inaccuracies might be expected where such additive errors occur, and for this reason the simple reversal of the lamp provided most of the advantage of the double-focusing adjustment without its serious disadvantage in complicating the procedure of focusing a head-lamp. Mr. Falge then expressed the opinion that the performance of two of the incandescent lamps supplied by Mr. Matthews was acceptable, to say the least; that of the third was good; and that of the fourth practically perfect. Mr. Matthews criticized the cut-off at the top of the lower beam as being too indefinite with one or two of the lamps; to which Mr. Falge replied that a moderately indefinite cut-off on the lower beam is desirable in practice.]

Chairman Dickinson:—I believe the audience would like to see now what can be done with the two adjustments, including some indication of how long it really takes to make the adjustments on the double-adjustment lamp.

Mr. Matthews:—Will you put one of those lamps in the double-adjustment head-lamp?

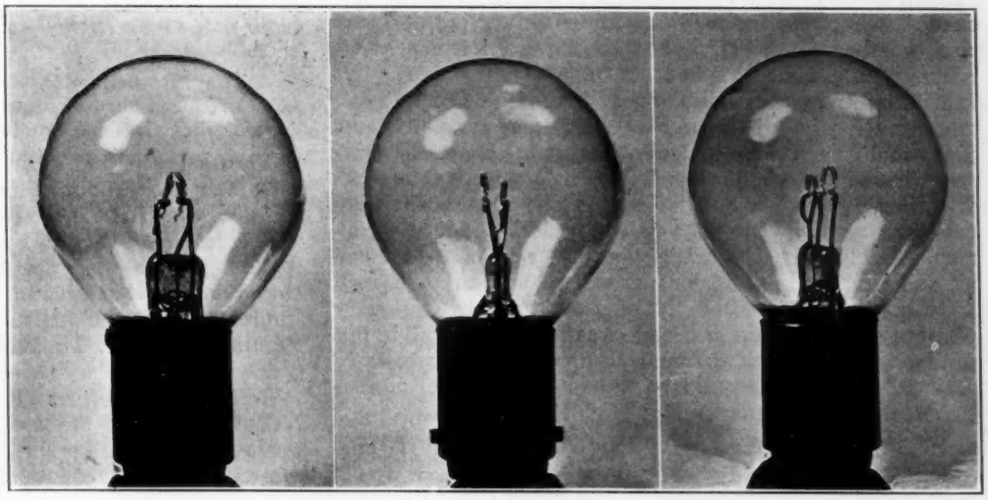


Fig. 8—Defective Double-Filament Lamp Used in Focusing Demonstration

These Three Views, Taken from Different Angles, Show the Two Filaments Badly Out of Alignment, Probably as the Result of an Accident in Manufacture. Although This Lamp Hardly Could Be Expected To Give a Good Light Pattern, the Results in a Single-Focusing Head-Lamp Were Thought by Some To Be Very Good, but Its Performance Was Criticized by the Advocate of Double-Focusing Head-Lamps

[One of the lamps supplied by Mr. Matthews was inserted in the double-adjustment head-lamp and focused by Mr. Falge. When it was demonstrated that the cut-off for the lower beam was less definite in this case than in the one criticized by Mr. Matthews, Mr. Matthews indicated that this might be improved by readjusting but declined an invitation to make such readjustment. Mr. Falge then suggested that it might be of interest to observe the performance of a really bad-looking lamp in the single-focusing head-lamp. One was selected which must have met with a serious accident in production, as shown by the three views in Fig. 8. When projected on the screen with the stereopticon Mr. Matthews expressed the opinion that such an incandescent lamp could not be expected to perform properly and, although Mr. Falge thought it did surprisingly well, Mr. Matthews criticized its performance.]

MR. FALGE:—Possibly both Mr. Matthews and I are biased in this matter. I am willing to accept the decision of the audience. I realize that this lamp does not perform perfectly. Considered on its own merits, however, without regard to the perfect job, I honestly believe that on the road one would be well satisfied with that head-lamp, both as regards the light distribution in the two beams and the tilt between the beams.

CONCLUSIONS OF THE BUREAU OF STANDARDS

CHAIRMAN DICKINSON:—The attitude of the Bureau of Standards in this matter has been mentioned two or three times tonight. Several members of the staff of the Bureau spent a day comparing single and double-adjustment lamps, as we are doing now. The net results, in our own conclusions, were very definite that the best adjustment we could get with the double-adjustment lamp was not in any case appreciably better than we could get with the single-adjustment lamp. In all cases we did all the aiming with the proper aiming method. When we tried to do any aiming with the double-adjustment lamp, the adjustments were invariably as bad as or worse than with the single-adjustment. That was the definite conclusion of the members of the Bureau of Standards. No appreciable improvement could be obtained with the two adjustments.

MR. MATTHEWS:—Then why are they necessary on some types of lamp? That is one point we should like to have cleared up. I am not engineer enough to know. It has been argued by the Bureau and other people that some types of two-filament lamp need them.

CHAIRMAN DICKINSON:—I am not very familiar with that statement as made by the Bureau, because Mr. Crittenden is in charge of that work. At the time it was made I was there more or less as an interested observer and member of the staff, but I believe I am correct in saying that that statement is more of a hypothetical statement than a practical one. From the geometry of the situation it is evident that with some types of lamp you would need a second adjustment if lamp filaments were badly enough displaced, but as a practical matter, with lamp filaments as they are at the present time, in selecting as bad ones as you can readily find, the conclusion which Mr. Crittenden and the rest of us arrived at was that no appreciable advantage was to be gained by the second adjustment, and that there was a very distinct disadvantage in that it was not only possible but probable that the adjustment would be much worse in service. I think this fairly represents the attitude of the Bureau of Standards.

MR. MATTHEWS:—In other words, if the bulbs were perfect we should not need this vertical adjustment on any type of two-filament lamp.

CHAIRMAN DICKINSON:—I do not think anyone believes for a moment that you would need that adjustment if the bulbs were perfect. However, I do not want to enter into that discussion.

ARGUMENT DETRIMENTAL TO PUBLIC SAFETY

MR. MATTHEWS:—I am merely asking for information. It has been said often that certain types must have the vertical adjustment, but we have not been able to find out what types they are. Nobody, apparently, could give us an expression on that. We have not been able to reach any conclusions regarding it. One manufacturer will say, "Mine does not need it," and another will say, "Mine does not need it but his does."

MR. FALGE:—Can you not leave that to the Bureau of Standards to decide for you? It has men who should be able to decide whether a device is sufficiently insensitive to be satisfactory with a single-focusing adjustment.

MR. MATTHEWS:—Unless they can tell us what the certain types are, we do not know. The manufacturer certainly thinks he is right; the Bureau thinks it is right. We are in the middle.

CONFERENCE RESOLUTION HAS BEEN RESCINDED

MR. DEVINE:—Some may gain the impression that Mr. Matthews presented his paper as a representative of the Eastern Conference of Motor-Vehicle Administrators. This is, of course, not so, and Mr. Matthews probably had no intention that such an impression should be made. Furthermore, his reference to the Conference resolution requiring two focusing-adjustments may give the impression that that resolution is still effective, but it has been rescinded and therefore does not represent the attitude of the Conference. Other references he made to the Conference and to the relations between the Conference States may result in the formation of erroneous opinions by the reader. However, it is not my intention to discuss these matters; I shall confine my remarks as closely as possible to the subject of focusing mechanisms.

The author makes reference to "cheap and poor construction, faulty and *complicated* adjustments," but perhaps he had no intention of referring to focusing mechanisms when he made this latter criticism. I am the ex-Chairman of the Conference Lighting Committee to which Mr. Matthews referred as sponsoring specifications incorporating two focusing-mechanisms on the first head-lamp of the double-filament type which was approved. I am content to refer the Society to the statement contained in my paper on focusing mechanisms[14], in which I say:

> The Massachusetts Registry of Motor-Vehicles has not favored the use of more than one focusing-mechanism since that construction was first proposed.

I think I need not go into detail about several matters, including the Illuminating Engineering Society's report of 1926, the attitude of the Bureau of Standards, a paper and a letter by R. N. Falge, and a letter from W. F. Anklam, which were not quoted completely by Mr. Matthews and on that account are very likely to give a false impression of the attitude of the respective authors. Furthermore, Mr. Matthews is not justified in stating conclusions based on these incomplete quotations.

Reference was made by him to Pennsylvania charts Nos. 1 and 2 and to "the peculiar results found." It is unfortunate that he did not include in his paper the matter referred to instead of much of the irrelevant

[14] See THE JOURNAL, June, 1927, p. 727.

matter therein contained. Certainly nothing is to be lost by presenting accurate data before the Society. Capable engineers carefully analyze such material and weigh it according to its value.

More Single than Double-Focusing Lamps in Use

Mr. Matthews has charged that "the automobile industry is comprised of the largest aggregation of copyists in existence." If he believes this I cannot see what conclusion he expects to reach by referring to the number of makes of automobile using double-focusing head-lamps. As a matter of fact, the actual number of single-focusing head-lamps now in use and being put into use far exceeds those of the double-focusing type. I refer to double-filament tilting-beam head-lamps. Perhaps the reason that any double-focusing head-lamps are used is because the action of two States has, up to the present, stopped the approval of any new head-lamps of the single-focusing type, and it is my understanding that the automobile manufacturers do not all want to use the same make of head-lamp.

Mr. Matthews intimates the ability of the State of Pennsylvania to write instructions for adjustment of double-filament head-lamps in such a practical form that the motorist will have no difficulty in complying with them. It is unfortunate that he did not present such instructions in his paper. In January I requested the proponents of multiple focusing to submit such instructions, and naturally I draw my own conclusions from their failure to do so. We have seen that a prominent consulting engineer was unable to follow instructions issued by the lamp manufacturer and to obtain the results for which such double-focusing head-lamps were designed. In Massachusetts, and I am informed that the same procedure is followed in Pennsylvania, we have found it impractical to give any specific instructions for adjusting such head-lamps in the head-lamp literature which we issue for use by the motorist. It would result in complications that would do more harm than good. We have, therefore, been compelled to rely upon the instructions issued by the manufacturer. Tables 4 and 5 show the result of adjustment complications, more improperly focused double-focusing head-lamps than single-focusing head-lamps.

Contention Based on Erroneous Assumption

The facility with which Mr. Matthews skips from focusing to aiming, to justify the *additional* vertical-focusing mechanism, is interesting. That point has been fairly well covered in my own paper. This issue should not be clouded by any double line of reasoning, nor can Mr. Matthews avoid the responsibility he has assumed by referring to the ease of operation of a screw-driver as contrasted with a wrench.

The subject of head-lamp adjustment has assumed National importance, and the complication of such mechanisms certainly brings us further from the goal we seek, all claims of the proponents of multiple focusing notwithstanding. No single feature of head-lamp design or construction retards the practical accomplishment of the intent of our headlight laws more than the present complication of adjustments. Mr. Matthews attempts to show greater familiarity of motor-car operators with the focusing mechanism than with the aiming mechanism. He does this by comparing the number who *know the use* of the adjusting screws with those who have ever *personally used* the nut under the S.A.E. mounting to tilt their head-lamps. What kind of a comparison is this which he asks a technical organization to consider?

His attempt to show that the use of the additional vertical adjustment for aiming does not disregard the best adjustment of the bulb and does not result in a distortion of the beam is based on the assumption that the head-lamp is placed on the car in a predetermined position before the car leaves the factory and that this setting is not disturbed in service. The first assumption is almost never true and the second one is never true, as a little practical experience would show the Pennsylvania authorities.

The claim that sockets will vary so much as to preclude any possibility of holding the filament within 3/64 in. of correct position is entirely unsupported by data, nor does Mr. Matthews even attempt to support his assertion by furnishing any.

Incorrect Interpretation Placed on Statements

In my paper I referred to the condition of head-lamps on 1156 vehicles stopped in succession in 1925. I said that 41 per cent were *improperly focused.* I am not given to making statements of this kind without meaning exactly what I say, and Mr. Matthews' interpretation of those defects as *improperly aimed* is not only incorrect but is without justification.

Again, in my paper I referred to the collection of data to show the ability of approved adjusters properly to adjust double-focusing head-lamps, and I made this statement: "After each adjustment the head-lamp was thrown completely out of adjustment before the succeeding adjuster touched it." Here also I meant exactly what I said, every lamp having been thrown out of focal adjustment and aiming adjustment as well. This explanation, which really should not be necessary, leaves Mr. Matthews' discussion of this particular matter hanging in thin air, because his discussion is based on an unwarranted and erroneous interpretation.

It hardly seems necessary to explain why the public is not informed as to the reason for reversing the position of the bulb in the head-lamp. Certainly car owners are competent to do that much and to select the better of two beam-patterns; and anyone who has had real experience in enforcement work knows that any technical explanation of the reasons for trying the bulb in two positions would befuddle the operator without accomplishing any practical object.

Mr. Matthews refers to two single-filament head-lamps which were approved in Pennsylvania in 1926, without specifying two focusing-mechanisms. His explanation that the certificates of approval which were issued for these lamps contained provisions relating to the future installation of a vertical adjustment, if necessary, does not explain Pennsylvania's requirement of two focusing-mechanisms on double-filament head-lamps, where they are no more necessary. Neither does the statement that Pennsylvania was not approving complete head-lamps when the majority of single-filament devices were approved alter the fact that an unjustifiable distinction has been drawn between head-lamps of the single and the double-filament types.

In his summary Mr. Matthews states:

> If we are to maintain safety on our highways, the question of price should not, and will not, be allowed to enter the discussion.

I know of no one except the authorities in Pennsylvania and New Jersey who have brought this question into the discussion.

In his conclusion he contends that the condition of maladjusted head-lamps is the concern of the law-enforcement authorities and not of the lamp manufac-

turers. As one of the former, I may qualify as being competent to bring this matter into the discussion, even under Mr. Matthews' definition.

In closing, I should like to clarify one matter which may be misunderstood from Mr. Matthews' paper. He handles the subject as a matter between the motor-vehicle authorities and the lamp or motor-car manufacturer. As a matter of fact, the lamp and car manufacturers probably would put two focusing-adjustments on their head-lamps, under compulsion, if they were permitted to do so. The State of Massachusetts has ample data, as presented in my paper and supplemented in the first part of this discussion, to show that two focusing-adjustments actually make night-driving conditions worse instead of better (see Tables 4 and 5). Therefore, we are not permitting the use of two focusing-adjustments on any new head-lamps submitted in Massachusetts. We would not be fulfilling our duty to the public if we failed to take that stand.

Not Trying To Disrupt Conference

MR. FALGE:—It is nearly 2 years since the last depressible-beam head-lamp was approved. Our responsibility for the safety of the motoring public demands that we end this argument soon and permit some of the devices of latest design, which have been denied the motorist for more than a year because of this division of opinion on approval, to be used on the roads where they will have a chance to reduce the appalling accident list charged to defective lighting.

It has been my experience that most car manufacturers and head-lamp manufacturers recognize fully the good work the Eastern Conference has done in improving the construction and performance of devices and are thoroughly in accord with it in this matter. It is only when the makers see something which they are convinced is fundamentally wrong, such as the double-focusing adjustment, that they object. Even then, had all of the States been in agreement, it is not improbable that the industry would have submitted. The manufacturers have at times been accused of trying to break up the Eastern Conference. It is not surprising that groups as different as are the manufacturers and the State officials should disagree at times, but it is ridiculous to assume that because of one such disagreement the manufacturers should endeavor to disorganize the States. As Mr. Matthews says in his paper, the only result of such a move would be to complicate the situation still further. Furthermore, if the industry were really trying to disrupt the Conference, one would hardly expect manufacturers such as the General Motors Corporation to voluntarily submit head-lamps to the State authorities for approval when such approval was unnecessary, as was the case recently with the Chevrolet head-lamp, for example.

Complete Quotations from Letter and Paper

There is one other matter in connection with Mr. Matthews' paper which I feel obliged to explain. In quoting extracts from my Illuminating Engineering Society paper and from my letter to George G. Cousins, of Toronto, Ont., he pays me the compliment of naming me a widely known and competent illuminating engineer. After establishing this reputation for me, he attempts to establish the merit of the double adjustment by partial quotations from my writings. Unfortunately, if correct, such quotations prove that I am anything but consistent in my views on technical matters. It happens, however, that both of these quotations are misleading, as will be readily evident upon reading the complete statements, which are as follows:

May 5, 1926.

Mr. George G. Cousins,
Assistant Laboratory Engineer,
Engineering Department,
Hydroelectric Power Commission of Ontario,
Toronto, Ont., Canada.

Dear Sir:

You wrote me on April 15 regarding the performance of two-filament depressible-beam head-lamps. I am enclosing copies of the I.E.S. paper referred to and our Progress Leaflet No. 3.

You state in your letter that you were able to obtain very satisfactory performance from two-filament lamps with headlight lenses designed for single-filament lamps. You seem to feel that the results were better than those from one of the devices approved by the Eastern Conference.

It has been our experience that devices designed for single-filament lamps are satisfactory when the two filaments are accurately positioned with respect to the focal point of the reflector. *The difficulty arises when commercial variations in incandescent lamps, sockets and reflectors are such that the filaments are located a small distance above or below their proper position. The vertical-focusing adjustment is provided to correct such variations.*

The other class of devices is designed to make the beams fairly insensitive to commercial variations in filament positioning. These devices are promoted with only the usual single adjustment.

The extent of commercial inaccuracies is fairly well established. The acceptable beam variation is, of course, a matter of judgment. In view of the fact, however, that variations of 4/64 in. above and below the focal point result, with ordinary equipments, in a change from a design tilt of say 2 deg. between beams to tilts of 0 and 4 deg. respectively, this variation, in our opinion, is hardly acceptable.

We believe the vertical adjustment should be avoided wherever possible. We recognize that there are practical difficulties in the way of added adjustment complications which will confuse the motorist and make it more difficult to obtain proper results than would be the case if but one focusing adjustment were provided. To eliminate the vertical adjustment, however, assuming that variations obtained with ordinary equipments are too great, head-lamps must be designed especially for the lamp.

The double-focusing mechanism really is a step away from the fixed-focus idea which many of those interested in better headlighting have been looking forward to for some time. Incandescent-lamp manufacturers have made exceptional progress in improving their product. Further improvement may be expected in the future. The head-lamp manufacturers have also been making their product more accurately. *It is supposed that at some time in the future variations will be reduced to the point where even the ordinary equipment will perform satisfactorily without the additional focusing-adjustment.*

Very truly yours,
R. N. FALGE,
Commercial Engineer.

[The portions in italics in the foregoing letter and the extract printed below are those quoted by Mr. Matthews.]

The following is an extract from an advance copy of my paper entitled Improved Motor-Vehicle Headlighting under the American Standard System presented before the Illuminating Engineering Society, September, 1925:

Although the tilt between the beams is not materially affected by small variations in the distance of

the upper filament above the focus of the reflector, it is sensitive to the positioning of the lower filament. In order to assure proper positioning of the lower filament with respect to the focus of the reflector, it is necessary to provide a focusing screw for vertical adjustment to compensate for variations in bulbs and head-lamp assembly. The focusing and aiming of the beams obviously then becomes somewhat more involved. This same limitation applies in attempting to use the lamp in equipments now provided on cars and designed for single-filament lamps, but, of course, not furnished with the vertical-focusing adjustment.

Much of the present headlighting is, however, done with another class of equipment in which reflectors with modified surfaces, or lenses with bending prisms, or a combination of both, are employed. These equipments can be designed to give the most desirable form of controllable beam, and without adding any complications to the procedure of adjustment followed with ordinary fixed-beam head-lamps. . . .

Falge's Position Previously Made Plain

I am at a loss to explain how Mr. Matthews could have offered his quotations from the foregoing in good faith, knowing that I should probably be present at this meeting. He is fully aware of my position in this matter and has been from the start of the controversy. He was present at the meeting last August of the Automotive Lighting Association and Eastern Conference Lighting Committee when a partial quotation from my letter to Mr. Cousins was made and at which time I asked that the complete letter be read. Several of those present expressed themselves as entirely satisfied that my position had not been compromised, even inadvertently, and Mr. Matthews did not indicate that the matter had not been explained to his entire satisfaction.

As regards the quotation from the Illuminating Engineering Society report, the first paragraph was read by Mr. Matthews last November at a hearing in Harrisburg when Pennsylvania officials requested the Guide Motor Lamp Mfg. Co. to show cause why its approval should not be revoked, since the latter refused to substitute a double-focusing adjustment for the single-focusing adjustment originally approved. I was not present at that conference but the minutes show that Mr. Michel answered as follows:

> I should like to answer that as best I can. In the first place, so far as Mr. Falge's paper is concerned, I believe that the reference made there was to the parabolic reflector, in which case his comments are true. I believe that I am not taking too much liberty in saying that Mr. Falge is unqualifiedly in favor of single focusing where the lighting device has been sufficiently compensated to permit such use to overcome the range of manufacturing variations in double filaments in the reflector. I believe further that Mr. Falge will state that where a device has not been compensated, such as a parabolic reflector, he is unqualifiedly in favor of a second adjustment. In the latter case, the device cannot be satisfactorily operated without the second adjustment. In the first case it can be.

In view of these facts it seems almost unbelievable that such quotations could appear in such a paper as Mr. Matthews'. If he has any explanation to offer, I shall be pleased to have it.

Mr. Matthews:—I assure you I had no intention of deliberately misquoting you for any purpose of my own, but the whole point resolved itself around the fact that we could not determine for ourselves or have anybody else determine for us which type is which.

Tilt Specifications Create Two Classifications

C. A. Michel[15]:—There are two subjects that I want to touch upon briefly. Among other things that came in for a little rap tonight was the S.A.E. mounting. I think it is generally realized that this is not the ideal mounting; it is not all that might be desired. If we will think back for about 6 years and remember the types of mounting that preceded the S.A.E. mounting and realize the improvement that it has brought about, I think we shall admit that it represents one of the outstanding factors that has contributed to progress in head-lamp adjustments. The Lighting Division is now about to consider the shortcomings of this mounting, and if anyone will send his opinions in writing to the Lighting Division at the Society's office, indicating what he thinks is a good head-lamp mounting and what it should do, the Lighting Division will take it into consideration.

The other subject is a little sidelight of historical interest. It seems to me that probably one of the most important things in this problem of two-filament head-lamps is the detail of tilt. The fact that two-filament head-lamps will permit the top of the upper beam to be depressed through a given angle has made it acceptable to the extent that it is being used today, because it provides advantages with which we are all familiar.

About the latter part of 1924 the Lighting Committee of the Eastern Conference invited several of the device manufacturers to meet with it to discuss specifications for double-filament head-lamps. Among these specifications was the matter of tilt, and it was decided that the top of the upper beam should depress to the top of the lower beam through an angle of 2 deg. minimum, 3 deg. maximum, 2 to 2½ deg. preferred.

By establishing this tilt, the devices were automatically thrown into two classifications; one was a sensitive or uncompensated device, and the other was the insensitive or compensated device. In the first classification we have the two filaments straddling the reflector axis. The upper beam is formed by warping the beam upward when illuminating the lower filament, and the lower beam is formed by warping the beam downward when using the upper filament. In this class of device, we have seen tonight that the amount of tilt is very sensitive to the placement of the lower filament. Obviously, if the Conference requirements pertaining to tilt are to be adhered to, we must have a beam which will tilt between 2 and 3 deg. In that type of equipment it is necessary to have a second adjustment if the filaments are to produce beams within that range of tilt.

In designing a compensating device, recognition is given to commercial variations in filament placement, and those portions of the device which react unfavorably to these variations in filament placement are desensitized, so to speak, and the light is tilted downward to the extent that, regardless of normal commercial variations throughout that range, the tilt is retained. Inasmuch as its filament is on the reflector axis, the compensated device then, in a sense, falls in the same classification as the single-filament lamp, which at no time in the past has been pressed for a second adjustment. It operates better than the commercial single-filament device for the reason that, first, it is less sensitive, and, second, I believe it is generally admitted that the two-filament bulb as made today is more accurate than the single-filament bulb.

It occurs to me, therefore, that anyone who is judging

[15] M.S.A.E.—Chief engineer, Guide Motor Lamp Mfg. Co., Cleveland.

a device or drawing conclusions with regard to the practicability of a single or double-focusing mechanism should bear in mind that opinions are tolerated, only facts are lacking.

L. A. WINE[16]:—Reference was made in Mr. Matthews' address to a letter written by W. F. Anklam, president of the C. M. Hall Lamp Co., which was read as it was written. At that time Mr. Anklam was of the opinion that the statements in that letter were right. Since that time, however, he has been convinced that he was entirely wrong, and he has written a letter giving good and sufficient reasons why he wrote that letter and also giving good and sufficient reasons why he has changed his ideas.

CHAIRMAN DICKINSON:—After all our discussion it must be evident to everyone that there really have been thoroughly honest differences of opinion not really influenced to any appreciable extent by commercial considerations. All are genuinely interested in arriving at the best result, to give maximum safety and convenience and general utility without undue regard to commercial advantages.

[16] A.S.A.E.—Sales manager, C. M. Hall Lamp Co., Detroit.

NAVAL AVIATION ACTIVITIES

ON Sept. 30, 1925, the Navy had 851 airplanes on hand. That number, in itself, would have seemed not so very far below the 1000 now aimed at, but of the 851 more than 500 were of war design, including nearly 200 of the big flying-boats that were built in great numbers for anti-submarine operations in 1918, and about 50 of the remainder were experimental. There were less than 300 machines that could properly be considered as useful in war by comparison with the best that could then be built.

Nine months later, almost on the day that the 5-year-program bill was receiving the President's signature, the total number had risen by only a dozen units, but the figure for the pre-1919 designs had fallen from 500 to 400, and the number applying to the 5-year program was decided, after careful consideration, to be just under 350.

The passage of another year and a month brought us to the first of August of this year, and to a total number of machines on hand still approximately constant at a little less than 900; but the war-time designs have now fallen off to barely 200, some of them extensively remodelled since 1921. Of the remainder, substantially 500 can fairly be considered as applicable to the figure of 1000 to be reached 4 years hence. Three hundred of the naval airplanes now in service have air-cooled engines of the most modern type. Furthermore, 318 additional machines are now on order for the earliest possible delivery, and all of them are of modern design and equipped with air-cooled powerplants.

PURCHASE OF 350 AIRPLANES PER YEAR PLANNED

It is reasonable to expect, if appropriations continue to be made available to purchase new airplanes in accordance with the original 5-year plan, that the number of useful machines on hand will continue to increase, after all wastage has been made up in each year, at the rate of approximately 100 per year and that we shall come in due course to our 1000. For that purpose we shall need to expend from $15,000,000 to $18,000,000 per year on new airplanes and engines, as against $13,500,000 provided during the present year; and the amount of money for maintenance and direct expenses of operation will be much increased. The number of airplanes purchased annually until 1932, to fit the program, will then average about 350. A definite place already is planned for every one of them. The present program represents a feasible schedule for realization at a comparatively early date, but no man can now say what the ultimate importance of naval aviation may be nor predict how many airplanes may be needed for naval purposes merely to maintain a proper peace-time organization, 8 or 10 years hence or at any other future period.

The corresponding progress in increase of personnel has also begun in accordance with a definite plan. On July 1, 1923, there were but 326 commissioned naval aviators and only a very small number of enlisted airplane pilots. On July 1 of this year the number of qualified officers had increased to 470, the total of enlisted pilots to 108, and the plan is, by adopting a regular schedule for the admission of about 280 candidates each year to the training course at Pensacola, to secure an increase to from 100 to 150 each year in the number of aviators available, rising finally, upon or soon after the completion of the 5-year equipment program, to a total of 864 officer aviators and about 4000 qualified enlisted men.

This will mean, if the authorized number of officers is continued as for the last several years, that 17 per cent of all the officers in the line of the Navy will be aviators, and somewhere around 20 per cent will be serving in connection with aviation in some capacity. It will mean, too, that practically all Naval Academy graduates who are physically and psychologically qualified will enter upon the full aviation course at Pensacola. It is already true that every young naval officer, upon the completion of his 4 years at the Academy, devotes several weeks to aviation indoctrination courses designed to acquaint him at first hand with the problems of the aviators and with the manner of conducting aerial operations in the Navy, although by no means to make him an aviator himself.

The numbers of personnel for the Navy proper are in addition to 130 officer and enlisted aviators for the Marine Corps. They are in addition, too, to the forces of the Reserve, which musters a growing number of patriotic civilians who have been trained as naval aviators and who undertake, by occasional brief periods of active duty and otherwise, to keep themselves in practice on their flying, conversant with current developments in the tactical employment of aeronautics, and ready for service at any time. Eighty-eight Reservists, most of them collegians and many of them students of aeronautical engineering, were so trained and added to the roster of reserve squadrons last year, and the number will be subject to steady expansion for a number of years before stabilization is reached at such a figure that the annual influx will balance the number of withdrawals.—From address by the Hon. Edward P. Warner, Assistant Secretary of the Navy for Aeronautics, before the Rotary Club of Troy, N. Y.

Engine-Cylinder Lubrication

By Lawrence T. Wagner[1]

Southern California Section Paper

Comparisons are made between the splash-feed and the force-feed systems of lubrication, the primary purpose being to suggest means for securing the best possible results from equipment already in use through promoting a better understanding of the variables in engine operation that affect cylinder lubrication directly. The variables analyzed are: viscosity of the lubricating oil, solid impurities accumulating inside the engine, volatility of the fuel, cylinder temperature, engine-speed, intake-manifold depression, and mechanical condition.

No single factor involved in the maintenance of automotive engines is of more importance than cylinder lubrication. Maximum efficiency and economy of operation, with low repair and replacement costs, cannot be secured unless pistons, piston-rings and cylinder-walls are correctly lubricated. As an indication of the magnitude of the friction between pistons and cylinder-walls, the following example will serve: A piston in a 5-ton truck having a rear-axle gear-ratio of 10 to 1 will travel approximately 1 mile up and down in the cylinder for every mile traveled by the truck in high gear. With a four-cylinder engine, this means 4 miles of total piston-travel to every mile of truck travel and, if low or intermediate speeds are used, the piston travel will increase in proportion. When it is realized that the total piston-wall area in such an engine is more than 300 sq. in., it is evident that a comparatively small variation in specific friction will affect mechanical efficiency greatly, as well as the rate of wear of these bearing surfaces. High temperatures, high speeds and more or less dirt in the form of solids deposited on cylinder-walls, still further complicate the problem of providing efficient cylinder lubrication in automotive units. Automotive-engine designers have constantly striven to provide a system of cylinder lubrication to meet these conditions better and in recent years have succeeded in overcoming many of the difficulties which formerly caused cylinder lubrication to be a rather uncertain factor in engine operation. However, there is still room for improvement along these lines, and no doubt further progress will be in evidence as new models are brought out.

It is not the primary purpose of this discussion to criticize or suggest changes in engine design but rather to suggest means of securing the best possible results from equipment now in use through promoting a better understanding of the variables in engine operation that affect cylinder lubrication directly. But the true significance of these variables and their relative importance cannot be understood without consideration of the different types of lubricating system as now incorporated in automotive engines insofar as they govern the delivery of lubricating oil to the cylinders. In all present-day automobile and truck engines, with one or two exceptions, the rotary motion of the crankshaft is utilized to supply lubricating oil to the cylinder-walls. This is true of both splash and force-feed lubricating-systems. In the splash-feed system, the lower part of the connecting-rod strikes a small body of oil maintained at a constant level in a dip trough and thus throws or splashes some of the oil up into the cylinders. In the force-feed system, the oil is forced through the crankshaft, emerging at the surface of the crankpin. A portion of this oil escaping from the lower connecting-rod bearing is then thrown by centrifugal force into the cylinders. In both systems, particularly at high engine-speeds and temperatures, more or less of the oil is whipped into a spray or mist by the action of the crankshaft. This oil mist permeates all interior parts of the crankcase and a portion of it finds its way into the cylinders.

Originally, some form of splash feed was employed in all automotive engines and it is only in comparatively recent years that the force-feed system has been developed. The trend is very strongly toward the use of force-feed lubrication and at present most engines are being equipped with this system. However, many automobile and truck engines still in service are equipped with splash feed, even though current models of the same make now have force-feed lubrication, and any consideration of the subject of cylinder lubrication involves a study of the characteristics of both systems. Furthermore, it should be realized that, while certain definite advantages are secured by the use of the force-feed lubricating-system, there are also advantages in the splash-feed system which are not possessed by the force-feed system. For instance, in the splash-feed system, it is necessary to employ only sufficient pressure to effect delivery of the oil to the dip troughs and the precautions required in the case of the higher pressures employed in the force-feed system are therefore unnecessary. The splash-feed system requires fewer parts and less piping and is not so liable to become clogged or to fail to deliver the required supply of oil. An even supply of lubricating oil to each of the several cylinders is not dependent upon any bearing clearances, as is the case with the force-feed system, and for this reason the rate of feed to the cylinders remains constant regardless of bearing wear. In starting a cold engine with the oil at a low temperature and having consequently a heavy body, it is possible with the force-feed system to have engine operation for some time with practically no delivery of oil to the cylinders, as the pressure on the system is not sufficient to force the heavy oil through the connecting-rod-bearing clearances. On the other hand, with the splash-feed system under similar conditions, some oil will be splashed by the action of the connecting-rods from the first moment of engine operation. While it is true that the force-feed system secures a more positive delivery of oil to all bearings on the crankshaft, it will be seen from the foregoing that, so far as cylinder lubrication is concerned, something is to be said in favor of the splash-feed system.

Important Variables in Engine Operation

The most important variables in engine operation which affect cylinder lubrication directly are as follows:

[1] Lubricating engineer, Standard Oil Co. of California, San Francisco.

(1) Viscosity of the lubricating oil
(2) Solid impurities accumulating inside the engine
(3) Volatility of the fuel used
(4) Cylinder temperature
(5) Engine-speed
(6) Intake-manifold depression
(7) Mechanical condition of the engine

Regarding the viscosity of the lubricating oil, the function of the oil delivered to the cylinders is to reduce friction between pistons and cylinder-walls to the lowest possible point and to prevent leakage past the pistons of gases under pressure. The ability of the oil to meet these requirements is determined largely by its body or viscosity, but this characteristic of the oil varies greatly with changes in its temperature.

The wide range of operating temperatures encountered in automobile engines causes a corresponding range of oil temperatures and viscosity. As the fluid friction in the oil becomes less with decrease in viscosity, it is desirable to operate engines at comparatively high temperatures to reduce piston friction. But at the highest temperature encountered the oil should still have sufficient body to withstand the pressure between piston and cylinder-walls and thus prevent metallic contact. The unit pressure between these bearing surfaces is comparatively low, and therefore complete separation of the surfaces can be maintained with oil of comparatively low viscosity. In fact, these surfaces can be fully protected and lubricated with an oil that has been thinned down to a point where it might not be able to withstand pressures in other bearings in the engine. In other words, unduly lowered viscosity of the oil generally will manifest itself first by damage to some other bearing surface in the engine. Where excessive cylinder wear is noted, or even where actual scoring or seizure occurs, the oil in use is seldom at fault and the real cause of the trouble should be sought elsewhere.

Until the engine has reached its normal operating-temperature, the oil will be heavier in body and the mechanical efficiency of the engine will be lower to the extent of the additional friction set up in this way. Aside from lowered mechanical efficiency, there is no objection to the heavier oil, provided it is sufficiently fluid to reach all points to be lubricated and to spread out in the form of an even film. Clearances between pistons and cylinders, as well as piston design, determine the maximum allowable viscosity. In this connection, it is perhaps fortunate that piston clearances in a cold engine are greater than in one which has been brought up to its operating temperature, as this permits the use of an oil heavier at lower temperatures than would otherwise be suitable.

The function of the piston-rings is to "seal" the combustion-chamber, or to prevent leakage past the piston. To be effective, this action of the piston-rings must be supplemented by the sealing effect of oil, which closes the minute gaps between the rings and the cylinder-wall and between the rings and the grooves in the piston. This function of the oil is dependent largely upon its viscosity and therefore is subject to some variation. If the oil is too heavy to reach the rings in sufficient quantity or if it is too light to withstand successfully the gas pressures that tend to break through the oil-film between the metallic surfaces, piston-seal will be impaired. If pistons, rings and cylinder-walls are in good mechanical condition, high viscosity is not required for perfect piston-seal. The gaps to be bridged by the oil are very small and the film established by comparatively thin oil is effective in maintaining the seal. Where piston-rings and piston-ring grooves become badly worn, heavier oil will assist in overcoming these defects. However, the use of extremely heavy oil for this purpose may do more harm than good, and if poor piston-seal develops in an engine using recommended oil, it is better practice to correct the mechanical condition that is responsible. Viscosity of the oil in use is also an important factor in distribution and should always be low enough to permit oil to reach the cylinder-walls in sufficient quantity to replace that destroyed or dislodged by the action of the pistons.

Accumulation of Solid Impurities

The solid impurities accumulating from engine operation are (*a*) carbonaceous matter, (*b*) road dust or silica and (*c*) metallic particles.

Carbon is formed in the engine by the decomposition of fuel and lubricating oil and from the effect of combustion temperatures. With the use of proper fuel and reasonably good carbureter-adjustment, fuel carbon is small in amount and most of the carbon formed is the result of the destruction of lubricating oil. Some of this carbon is deposited on the surfaces of the combustion-chamber and in other interior parts of the engine, and some of it becomes mixed with the lubricating oil in a finely divided state. Carbon accumulating in the oil itself tends to increase its viscosity, and in this way the oil may become too heavy to permit full distribution. If the particles of carbon deposited in the oil are of sufficient size and hardness they will have an abrasive action, causing undue wear of the cylinders and pistons. It is therefore desirable to use lubricating oil that will form the least possible amount of carbon and that this carbon be of such a nature that it will not prove injurious to bearing surfaces.

Where a truck or automobile is operated under dusty conditions, dust taken into the engine through the carbureter and through the crankcase breather-pipe may cause excessive wear of cylinders and pistons. The dust problem is not so serious where operation takes place on paved highways, although there is some dust in the air at all times and places. Air-cleaners, as installed on some equipment, are effective and beneficial to the extent that they prevent the entrance of injurious solids, and their use should be encouraged, particularly under dusty operating-conditions.

While it is true that there is always some wear of bearing surfaces, the amount of metal in the form of small particles accumulating in the engine between ordinary periods of draining is exceedingly small if the engine is in reasonably good mechanical condition and correctly lubricated. It is during the process of "breaking-in" a new engine that this factor is of more importance, because considerable metal is removed from the cylinder and piston-walls as they lap themselves in. To guard against the abrasive effect of these metallic particles in a new engine, frequent renewals of the oil supply should be made.

Solid impurities of all kinds accumulating in the oil have a tendency to collect on the oil strainer or screen, clogging it and preventing free flow of the oil to the pump. If allowed to accumulate for a long period of operation, the stoppage of oil going to the pump may become complete enough to rob the cylinders of the necessary oil and thus impair their lubrication. Various kinds and types of filtering device installed on automotive equipment are of benefit in removing solid impurities from the oil, and their value is proportional to the quantity of impurities so removed. Too much reliance should not be

placed upon them, as it is possible for solids to accumulate in an engine equipped with a filtering device.

Volatility of Fuel and Cylinder Temperature

The volatility of the fuel in use is important in connection with cylinder lubrication, because the presence of liquid fuel in the cylinders interferes with the proper functioning of the lubricating oil on the cylinder-walls. If the fuel has not sufficient volatility to assure complete gasification in the combustion-chambers, any ungasified portion of it will dilute the oil on the cylinder-walls and wash some of it off so that complete separation of bearing surfaces can no longer be maintained. At the same time piston-seal is impaired and some of the liquid fuel gets down into the lower crankcase where it mixes with the lubricating oil and reduces its viscosity. This fuel dilution of the oil may continue to a point where the oil no longer possesses sufficient viscosity to lubricate the cylinders correctly, and undue friction and wear will result.

In addition to its effect on the viscosity of the lubricating oil, the temperature of the cylinder-walls has another important influence on cylinder lubrication. Fuel in gaseous form coming into contact with cold surfaces is partly condensed, diluting the oil on the cylinder-walls and impairing lubrication. Water vapor formed in the combustion-chambers as a product of combustion is also condensed upon its contact with cold cylinder-walls and becomes mixed with the oil. Water formed in this way will, under certain conditions, prevent cylinder lubrication and may even cause the rusting of cast-iron surfaces. It would be highly desirable if the cylinders could be warmed before the engine is started and maintained at the proper temperature at all times during operation. As this is not practicable, the warming-up of a cold engine by engine operation should be conducted with due regard to the possible damage that may occur while the cylinder-walls are at comparatively low temperatures.

Effect of Engine-Speed

As oil-pumps of positive displacement are generally used in automotive equipment and as these pumps are driven at a speed proportional to the engine-speed, the delivery of oil by the pump is in direct ratio to the speed of the engine. From the standpoint of cylinder lubrication this seems to be an ideal arrangement, as the pump delivers a predetermined quantity of oil for each stroke of the piston, regardless of engine-speed. But delivery of oil to the cylinders is not directly proportional to the engine-speed, because it is not delivered directly to the cylinders, and this fact gives rise to many of the difficulties encountered in maintaining lubrication without excessive oil consumption.

While it is true that the delivery of oil by the pump is proportionate to the engine-speed, certain other factors modify the supply reaching the cylinders. The oil is pumped to the dip troughs or to the oil passage in the center of the crankshaft, but the proportion of such oil that reaches the cylinders is dependent upon the viscosity of the oil as well as upon the speed of the crankshaft. In other words, the proportion of oil pumped that reaches the cylinders per revolution of the engine increases with higher engine-speeds and lower oil-viscosities. For example, a crankshaft turning at 1000 r.p.m. will receive from the oil-pump twice as much oil as would be received at a speed of 500 r.p.m., but at the higher speed more than twice as much of this oil would be thrown up into the cylinders. Furthermore, if the temperature of the oil were higher, a still greater proportion of the oil delivered to the crankshaft would be deposited on the cylinder-walls at the higher speed. The capacity or rate of delivery of the oil-pump is designed by the manufacturer to assure the delivery to the cylinders of a sufficient quantity of oil at low engine-speeds and low temperatures. Consequently, at high speeds and high temperatures, a greater quantity of oil is delivered to the cylinders than is required for their lubrication. The greater the quantity of oil deposited on the lower cylinder-walls is, the greater is the amount that will work past the pistons into the combustion-chambers of the engine. Surplus oil at this point means high consumption and excessive carbon formation.

To reduce the quantity of oil supplied to the cylinders at high speeds and temperatures, some form of regulating device is installed in most automotive engines to reduce the relative quantity of oil delivered to the crankshaft at the higher speeds. This is generally some form of bypass valve that allows a certain portion of the pump output to be returned directly to the oil-sump. As the pressure in the oil lines caused by higher pump-speed increases, this spring-loaded bypass-valve opens, relieving the pressure and cutting down the quantity of oil delivered to the cylinders. This action of the bypass valve is, however, a distinct disadvantage in cold starting and during the warming-up process, particularly in connection with the force-feed systems. At lower temperatures the oil, because of its comparatively heavy body, has high resistance to flow and more pressure is required to force it through the bearings in sufficient quantity to supply the cylinders. But the opening of the bypass valve keeps the pressure down and most of the oil delivered by the pump is bypassed instead of going through the bearings. Because of this condition, it frequently happens that cold engines are operated for some time without enough oil reaching the cylinders. Raw fuel and condensed water-vapor present in the cylinders under such conditions quickly impair the oil-film left from previous operation, and serious damage may occur before a fresh supply of oil is spread over the bearing surfaces.

While the oil bypass or relief valve is effective to some extent in preventing over-oiling of cylinders, certain operating conditions always exist in which too much oil will be supplied to the cylinder-walls. Because of the inability of the lubricating system itself to regulate the amount of oil supplied to the cylinders under all operating conditions, efforts of automotive designers of recent years have been directed to the installation of devices on the piston that will restrict the amount of oil passing up into the combustion-chambers. Specially designed piston-rings, bleeding of the pistons and other devices of a similar nature have been resorted to for this purpose. These devices are beneficial where they are successful in controlling the oil passing to the upper cylinder-walls, provided they do not rob them of their proper supply of oil. Reduction of cylinder oil-feed is frequently carried too far in an effort to increase oil mileage, and it should be borne in mind that too much oil is better than not enough.

Intake-Manifold Depression

Several factors influence the upward and downward movement of lubricating oil on the cylinder-walls. In traveling up and down in the cylinder, the piston carries oil to the top of the bore and assists in spreading it evenly over the swept surfaces. The upward movement of the oil is restricted to some extent by the force of

gravity, but this factor is of minor importance. Gas pressures above and below the piston have a much greater effect in determining the amount of oil that reaches the upper cylinder-wall and combustion-chamber.

On the intake stroke, the pressure above the piston is less than the atmospheric pressure below, the difference depending upon piston speed and throttle opening. The greater pressure below the piston tends to carry oil upward on the cylinder-wall and, if there were no opposing pressure, would soon result in flooding the combustion-chamber. On the compression and combustion strokes, the pressure above the piston is much greater than below it, and this tends to prevent oil from getting above the piston. When the engine is operated with very small throttle-opening, as in idling or under light loads, intake-manifold depression is high and little, if any, compression pressure is developed during the compression stroke. Combustion and exhaust pressures are correspondingly lower and, under such conditions, a tendency always exists for oil to accumulate above the piston. This is evidenced by the cloud of oil smoke emerging from the exhaust pipe when the throttle is opened suddenly after prolonged idling of the engine. On the other hand, operation of the engine with full throttle-opening restricts the movement of the oil upward in the cylinder and, under certain conditions, may cause a failure of cylinder lubrication. When it is necessary to maintain engine operation for any length of time with wide-open throttle, it is advisable, if opportunity permits, to close the throttle momentarily. This will result in replenishing the supply of lubricating oil on the upper cylinder-wall.

Mechanical Condition of the Engine

The mechanical condition of cylinder-walls, pistons and piston-rings must be such as to permit the lubrication of these bearing surfaces when supplied with the correct oil for this purpose. If the surfaces have been properly finished and proper clearances provided when the engine is new, no change will take place which will impair the continuous lubrication of the cylinders unless the smoothness of the surfaces has been destroyed by scoring or scuffing. Changes that occur during the life of the engine due to the gradual wear of the surfaces permit a larger proportion of the oil delivered to the cylinders to reach the combustion-chamber and, for this reason, it generally happens that consumption increases with age.

The piston-rings are the most important factor in fixing the rate of oil consumption and, as the wear of the rings is more rapid than that of other bearing surfaces, it frequently is advisable to renew piston-rings when consumption is unduly increased. The wear of the face of the rings in contact with the cylinder-walls is not so important as wear of that portion of the rings in contact with the surfaces of the ring grooves in the pistons. The former merely results in widening the gap between the ends of the piston-ring, which does not affect oil consumption materially, but the latter permits motion of the rings in the grooves and, where this movement is appreciable, oil consumption increases rapidly.

In engines equipped with splash-feed systems of lubrication, comparatively small chance exists for variations in the mechanical condition of the lubricating system that will directly affect cylinder lubrication. So long as dip troughs are kept supplied with oil, proper delivery to the cylinders is assured. When for any reason the lower crankcase is taken down, it is necessary to guard against any possible changes or damage which might change the relative level of the oil in the dip troughs. If a new gasket is installed of a different thickness than the previous one, the dippers on the bottom of the connecting-rods will have a greater or lesser dip in the oil, depending upon the change in thickness of the gasket. If any change is made in the shimming of the lower connecting-rod bearings, the amount of dip may be changed and this will affect delivery of the oil to the cylinders. As a comparatively small variation in the amount of dip will greatly vary the supply of oil to the cylinders, it is necessary to maintain this condition as originally established by the designer of the engine.

In engines equipped with the force-feed system of lubrication there may be considerable variation in the supply of oil to the cylinders as operation of the engine is continued. Connecting-rod-bearing clearances gradually increase with wear, and a greater proportion of the oil delivered by the pump will therefore escape from these bearings and be delivered to the cylinders. If, for any reason, clearances in one or more of these bearings become greater than in some of the others, the distribution of oil to the various cylinders will become uneven. More oil will be delivered to those cylinders where the greater bearing-clearances exist, and a correspondingly less amount will be delivered to the other cylinders. In repairing and overhauling these engines, if any work is done on the connecting-rod bearings, it is necessary that precautions be taken to assure the same clearances for all these bearings.

It is true that, in both systems, a possibility exists for complete or partial stoppage of oil pipes and passages, which may reduce the supply of oil going to one or more of the cylinders. Solid impurities accumulating in the oil tend to build up deposits in small passages where the speed of the oil is low and where sharp turns or bends promote such accumulations. During overhauls, it is desirable that all passages be cleaned and carefully examined to assure free flow of a normal amount of oil. As the oil-pump runs constantly in a bath of oil, the wear of its working parts is extremely small and failure of the oil supply caused by worn pump-parts seldom occurs except after extremely long operation.

Reciprocating Balance in Engines of Six and Eight Cylinders

By M. V. DAVIDSON[1] *Illustrated with* DIAGRAMS

MATHEMATICAL analyses of the force required to accelerate the reciprocating parts of six and of eight-cylinder engines and of the axial and perpendicular components of the force needed to accelerate the connecting-rod are presented by the author. He then shows mathematically that the division of the connecting-rod into reciprocating and rotating elements is correct theoretically.

Having obtained exact expressions for the forces required to accelerate the reciprocating parts and the connecting-rod and having shown that the usual treatment given the connecting-rod is correct theoretically, mathematical study is made of the reciprocating balance of six and of eight-cylinder engines for comparative purposes and comparison is made numerically between six and eight-cylinder engines having equal total weight of reciprocating parts. A study of the angular acceleration of the connecting-rod is also presented in the article.

In conclusion the author states that the six-cylinder engine appears to possess axial balance superior to that of the eight-cylinder engine and that the latter is superior to the six-cylinder engine from an oscillatory standpoint.

RATHER widespread belief exists among engineers that the reciprocating balance of "in-line" six and eight-cylinder engines is theoretically perfect; therefore, this paper has the object of calling attention to the incorrectness of this view and of making some comparisons between six and eight-cylinder engines.

So far as I am informed, M. Normand, of France, first called attention to the apparent reciprocating balance of "in-line" engines having three cranks set at 120 deg. to each other. Balance is indicated for such an arrangement when use is made of the familiar but approximately accurate equation, in connection with Fig. 1,

$$F = MC\omega^2 (\cos \phi + \frac{C}{R} \cos 2\phi) \qquad (1)$$

Equation (1) will indicate also a state of perfect balance for four cranks set at 90 deg. to each other and, under these two crank-arrangements, fall the in-line six and eight-cylinder engines having pairs of cranks set at 120 and at 90 deg. respectively. I will attempt to show that theoretical balance does not exist for these crank arrangements with finite connecting-rods, but that, with common ratios of rod to crank, the six-cylinder engine is almost in perfect balance and the eight-cylinder engine somewhat less so; also, that with small ratios of rod to crank the unbalance is appreciable in both cases, and particularly so for the eight-cylinder engine.

FORCE REQUIRED TO ACCELERATE RECIPROCATING PARTS

To demonstrate the foregoing assumptions, the following deductions are given for theoretically exact expressions for the force to accelerate the reciprocating parts, and for the components of the force to accelerate the connecting-rod. Referring to Fig. 1, two methods can be used for the deduction of the expression for the force to accelerate the reciprocating parts. One method is to take the sum of the radial acceleration of the wristpin center S with respect to the crankpin center P, and the component parallel to the connecting-rod of the radial acceleration of the crankpin center P with respect to the shaft center O, as the component parallel to the connecting-rod of the acceleration of the reciprocating parts.

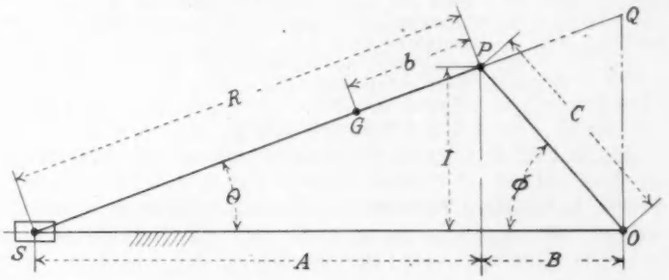


FIG. 1—DIAGRAM OF FORCE REQUIRED TO ACCELERATE THE RECIPROCATING PARTS

Then, since the motion of the reciprocating parts is along the line OS, dividing the component thus found by the cosine of the connecting-rod angle θ will give the expression for their acceleration. This expression multiplied by the mass of the parts represents the force required for the acceleration.

The velocity of S with respect to P is found readily by the method of instant centers, and the equation for the accelerating force thus obtained first appears as,

$$F = \frac{WV^2}{g} \left[\frac{\cos^2 \phi}{R \cos^3 \theta} + \frac{\cos (\phi + \theta)}{C \cos \theta} \right] \qquad (2)$$

and, when the function of θ and $(\phi + \theta)$ are expressed in terms of functions of ϕ, the equation takes the more usable form,

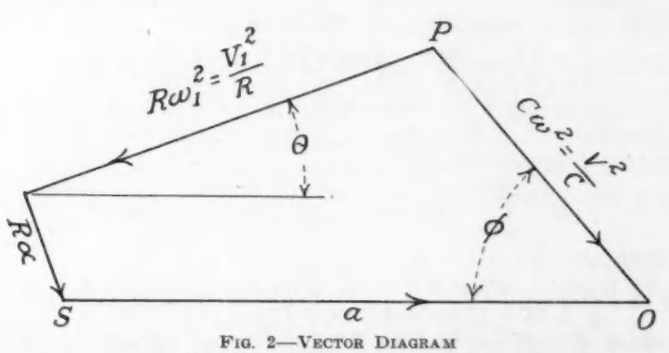


FIG. 2—VECTOR DIAGRAM
The Diagram Is Drawn with Sides in Conformity with the Positions of Fig. 1 and Illustrates the Accelerations Involved

[1] Department of mechanical engineering, University of South Dakota, Vermillion, S. D.

$$F = \frac{WV^2}{g}\left[\frac{R^2\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{3}{2}}} - \frac{1-\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{1}{2}}} + \frac{\cos\phi}{C}\right] \quad (3)$$

where $K = R^2 - C^2$. The other method of obtaining equation (3) is through the consideration of two aspects of the acceleration of P with respect to O, as follows: First, as a point in the crank and, second, as a point in the connecting-rod. For the acceleration of P with respect to O as a point in the crank must equal its acceleration with respect to S together with the acceleration of the latter with respect to O; and a vector diagram representing these accelerations must close. Fig. 2, drawn with sides in conformity with the positions of Fig. 1, illustrates the accelerations involved.

Let

$C\omega^2 = \frac{V^2}{C}$ = Radial acceleration of P relative to O

$R\omega^2 = \frac{V_1^2}{R}$ = Radial acceleration of P relative to S

$R\alpha$ = Tangential acceleration of P relative to S
a = Acceleration of S relative to O
C = Crank length in feet
R = Connecting-rod length in feet
ω = Angular velocity of the crank in radians
V = Linear velocity of the crankpin center in feet per second
ω_1 = Angular velocity in radians per second of the crankpin center relative to S
V_1 = Linear velocity of the crankpin center relative to S
α = Angular acceleration of the connecting-rod relative to S
ϕ = Crank angle
θ = Connecting-rod angle

If, in Fig. 1, C represents the crankpin velocity, then by the method of instant centers PQ will represent the crankpin velocity relative to S, which latter is a point of the reciprocating parts, and,

$$V : V_1 = C : \overline{PQ} \quad (4)$$

$$V_1 = \frac{V \times \overline{PQ}}{C} \quad (5)$$

$$\omega_1 = \frac{V \times \overline{PQ}}{CR}, \text{ as } V_1 = R\omega_1 \quad (6)$$

$$\omega_1^2 = \frac{V^2 \times \overline{PQ}^2}{C^2R^2}, \text{ as } \overline{PQ} = \frac{C\cos\phi}{\cos\theta} \quad (7)$$

and,

$$\omega_1^2 = \frac{V^2\cos^2\phi}{R^2\cos^2\theta} \quad (8)$$

Summation of the vertical components of the vector diagram in Fig. 2 gives,

$$R\alpha\cos\theta = C\omega^2\sin\phi - R\omega_1^2\sin\theta \quad (9)$$

from which,

$$\alpha = \frac{C\omega^2\sin\phi}{R\cos\theta} - \omega_1^2\tan\theta \quad (10)$$

Summation of the horizontal components of Fig. 2 gives,

$$a = R\omega_1^2\cos\theta + C\omega^2\cos\phi - R\alpha\sin\theta \quad (11)$$

Substituting the values of ω_1^2 and α of equations (8) and (10) in equation (11), there results,

$$a = V^2\left[\frac{\cos^3\phi}{R\cos\theta} + \frac{\cos\phi}{C} - \left(\frac{\sin\phi\tan\theta}{C} - \frac{\cos^2\phi\tan^2\theta}{R\cos\theta}\right)\right] \quad (12)$$

Eliminating θ in terms of ϕ and substituting for all functions of ϕ in terms of cosine ϕ, and rearranging terms, there results,

$$a = V^2\left[\frac{R^2\cos^2\phi}{(R^2-C^2+C^2\cos^2\phi)^{\frac{3}{2}}} - \frac{1-\cos^2\phi}{(R^2-C^2+C^2\cos^2\phi)^{\frac{1}{2}}} + \frac{\cos\phi}{C}\right] \quad (13)$$

from which,

$$F = \frac{WV^2}{g}\left[\frac{R^2\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{3}{2}}} - \frac{1-\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{1}{2}}} + \frac{\cos\phi}{C}\right] \quad (14)$$

where $K = R^2 - C^2$. The first two terms of expression (14) inside the brackets represent the angularity effect of the connecting-rod, or "secondary effect," and the last term inside the brackets represents the crank-angularity effect, or "primary effect."

Axial and Perpendicular Components of the Force Required To Accelerate the Connecting-Rod

Referring again to Fig. 1, consideration of the acceleration of point G, the mass-center of the connectin-rod, relative to the crankpin center P, together with the acceleration of P relative to the center of the shaft O, will yield the absolute acceleration of the rod's center of mass; and the axial and perpendicular components of this, multiplied by the mass of the rod, will give the forces acting respectively parallel and perpendicular to the axis of the engine for the acceleration of the connecting-rod. Drawing the vector diagram shown in Fig. 3, representing the accelerations of the mass-center and crankpin center as already outlined and with sides in conformity with the positions of the members of Fig. 1, we have

$b\omega_1^2$ = Radial acceleration of the rod's mass-center relative to the crankpin center
$b\alpha$ = Tangential acceleration of the rod's mass-center relative to the crankpin center

The description of the other symbols and combinations is identical with that for Fig. 2.

Considering the horizontal components of the accelerations, shown in Fig. 3, for the determination of the axial component of the acceleration of the rod's mass-center, we have,

$$a_1 = b\omega_1^2\cos\theta + b\sin\theta\left(-\frac{C\omega^2\sin\phi}{R\cos\theta} + \omega_1^2\tan\theta\right) + C\omega^2\cos\phi \quad (15)$$

from which, by the substitution of the previously determined value of ω_1, the expression of θ in terms of ϕ, and the substitution in terms of the cosine ϕ for all other functions of ϕ, there results,

$$a_1 = V^2\left[\frac{b}{R}\left(\frac{R^2\cos^2\phi}{(K+C^2\cos^2\phi)_2} - \frac{1-\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{1}{2}}}\right) + \frac{\cos\phi}{C}\right] \quad (16)$$

from which,

$$F_1 = \frac{W_1V^2}{g}\left[\frac{b}{R}\left(\frac{R^2\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{3}{2}}} - \frac{1-\cos^2\phi}{(K+C^2\cos^2\phi)^{\frac{1}{2}}}\right) + \frac{\cos\phi}{C}\right] \quad (17)$$

in which W_1 is the weight of the connecting-rod and b, of Fig. 1, is the distance in feet from the rod's mass-center to the center of the crankpin. The value of K is $R^2 - C^2$, as before, and F_1 represents the total axial inertia-effect of the connecting-rod.

It should be noted that, if b is equal to R, then F_1 becomes the force to accelerate a purely reciprocating weight, see equation (14); further, that it will become the horizontal component of a revolving mass centered at the crankpin if b becomes zero.

Next, considering the vertical components of the accelerations of Fig. 3, for the determination of the perpendicular component of the acceleration of the rod's mass-center, we have,

$$a_2 = C\omega^2\sin\phi - b\omega_1^2\sin\theta - b\alpha\cos\theta \quad (18)$$

By substitution as in the preceding manner

$$a_2 = \frac{V^2\sin\phi}{C}\left(1 - \frac{b}{R}\right) \quad (19)$$

from which,

$$F_2 = \frac{W_1V^2\sin\phi}{gC}\left(1 - \frac{b}{R}\right) \quad (20)$$

in which F_2 represents the total inertia-effect of the rod perpendicular to the axis of the engine.

It should be noted that, if b is equal to R, then F_2 will equal zero, as the weight would then be entirely recipro-

cating; also, if b is equal to zero, then F_2 will equal the perpendicular component of the centrifugal force of the weight of the rod with mass-center at the crankpin center.

Division of the Connecting-Rod into Reciprocating and Rotating Elements Theoretically Correct

Examination of equation (17) will make plain the fact that F_1, the axial component of the force to accelerate the connecting-rod, is identical with that obtained by the usual procedure of dividing its weight into reciprocating and rotating elements proportioned in accordance with the location of the center of mass. Thus, by the substitution of letters for the expressions inside the parentheses, equation (17) becomes,

$$F_1 = \frac{W_1 V^2}{g}\left[\frac{b}{R}(X - T) + N\right] \qquad (21)$$

Dividing the rod into reciprocating and rotating weights with W_1 equal to the sum of the two, W_s representing the reciprocating weight and W_p the rotating weight, we have,

$$F_1 = \frac{W_s V^2}{g}(X - T + N) + \frac{W_p V^2}{g} N \qquad (22)$$

The first term at the right of equation (22) represents the force to accelerate the reciprocating part of the rod, and the last term at the right represents the axial component of the centrifugal force of the rotating part of the rod.

If it can be shown that equations (21) and (22) are identical, that fact will prove that the usual treatment given the rod is theoretically correct. It can be shown, as follows: In equation (21), $\frac{b}{R} W_1 = W_s$, so that,

$$F_1 = \frac{W_s V^2}{g}(X - T) + \frac{W_1 V^2}{g} N \qquad (23)$$

Equation (22) can be written,

$$F_1 = \frac{W_s V^2}{g}(X - T) + \frac{N V^2}{g}(W_p + W_s) \qquad (24)$$

and, as $W_1 = W_p + W_s$, equation (22) therefore becomes,

$$F_1 = \frac{W_s V^2}{g}(X - T) + \frac{W_1 V^2}{g} N \qquad (25)$$

Hence, equations (21) and (22) are identical, since equations (23) and (25) are the same.

Six and Eight-Cylinder Engines

Having obtained exact expressions for the forces to accelerate the reciprocating parts and connecting-rod, and having shown that the usual treatment given the connecting-rod is theoretically correct, we can now proceed to the examination of the condition of reciprocating balance of six and of eight-cylinder engines. In treating reciprocating balance, the axial component of the rotating part of the connecting-rod can be omitted, since the entire effect of that part of the rod can be neutralized by the addition of other connecting-rods, or, by the addition of a balance weight; also, mathematical examination of equation (20), which represents the perpendicular component of the force to accelerate the rod, will show that, for three cranks set at 120 deg., or for four cranks set at 90 deg., the perpendicular components are in perfect balance. Therefore, the only force necessary to examine in connection with the balance of the reciprocating parts is that given by equation (14), in which W represents the weight of the purely reciprocating parts together with the fraction of the weight of the connecting-rod borne by the wristpin, this fraction being determined, as stated, by the position of the rod's mass-center.

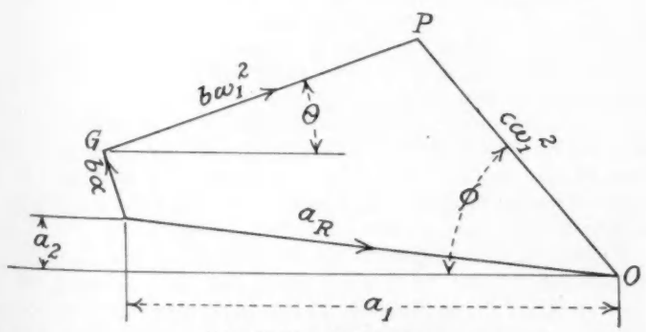


Fig. 3—Vector Diagram
The Diagram Represents the Accelerations of the Mass-Center and Crankpin Center. Its Sides Are Drawn in Conformity with the Positions of Fig. 1

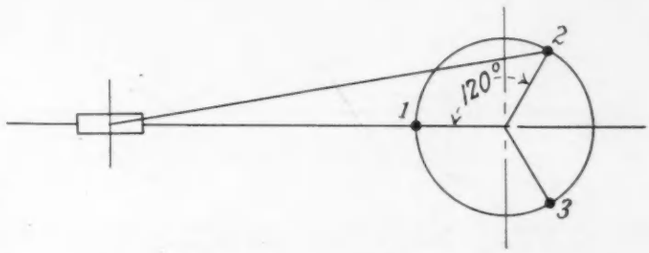


Fig. 4—Three-Crank Arrangement with One Crank on Head Dead-Center

Mathematical examination of the application of the third term within the brackets of equation (14) to the three cranks set at 120 deg. and the four cranks set at 90 deg. will show that this term becomes zero for all positions in both cases; in other words, the primary forces are in balance. Therefore, the only part of the expression requiring application is represented by the first two terms inside the brackets. These terms represent the secondary, or connecting-rod, angularity effect. Referring to Fig. 1, in connection with equation (14), it will be found that the expression will reduce to the form,

$$F = \frac{W V^2}{g C^2}\left(\frac{R^2 B^3}{A^3} - \frac{H^3}{A} + B\right) \qquad (26)$$

where A and B are respectively the projections of the connecting-rod and the crank upon the axis of the engine, and H is the perpendicular distance of the crankpin center from the axis. Dropping term B from equation (26) for the reason given, and also dropping for the present the constant $WV^2 \div g$, the remaining expression is,

$$\frac{1}{C^2}\left(\frac{R^2 B^3}{A^3} - \frac{H^3}{A}\right) \qquad (27)$$

Expression (27) should prove to be zero for any position, on summation for all the cranks if the engine is in perfect reciprocating balance. The expression will first be applied to the three-crank arrangement with one crank on head dead-center, as in Fig. 4. For cranks Nos 1, 2 and 3, expression (27) becomes, respectively, expression (28), (29), or (30).

$$\frac{1}{C^2}\left(\frac{R^2 C^2}{R^3} - 0\right) \qquad (28)$$

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.25\, C^2}{A_2^3} - \frac{0.75\, C^3}{A_2}\right) \qquad (29)$$

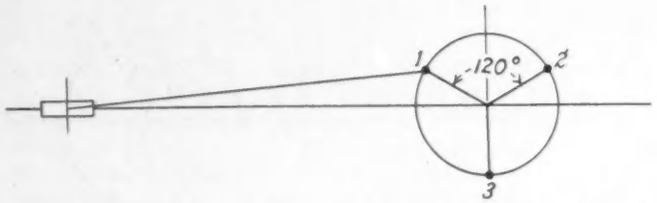


FIG. 5—THREE-CRANK ARRANGEMENT WITH ONE CRANK LOCATED AT AN ANGLE OF 90 DEG. WITH THE AXIS OF THE ENGINE

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.25\,C^2}{A^3_2} - \frac{0.75\,C^2}{A_2}\right) \quad (30)$$

A summation of the expressions (28), (29) and (30) gives,

$$\left(\frac{1}{R} + \frac{0.5\,R^2}{A^3_2} - \frac{1.5}{A_2}\right) \quad (31)$$

When multiplied by $WV^2 \div g$, expression (31) gives the unbalanced inertia-force for a combination of three cranks set at 120 deg. to each other and with one of the cranks on head dead-center. This equation is,

$$F = \frac{WV^2}{g}\left(\frac{1}{R} + \frac{0.5\,R^2}{A^3_2} - \frac{1.5}{A_2}\right) \quad (32)$$

and is not equal to zero since A_2 is not equal to R.

Fig. 5 represents a second application of expression (27) to the three-crank arrangement. Here, one crank is located at an angle of 90 deg. with the axis of the engine. For cranks Nos. 1, 2 and 3, expression (27) becomes, respectively, expression (33), (34), or (35).

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.75\,C^2}{A^3_1} - \frac{C^2}{4\,A_1}\right) \quad (33)$$

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.75\,C^2}{A^3_1} - \frac{C^2}{4\,A_1}\right) \quad (34)$$

$$\frac{1}{C^2}\left(O - \frac{C^2}{A_2}\right) \quad (35)$$

Adding these three values, expressions (33), (34) and (35), and multiplying by $WV^2 \div g$ gives the unbalanced inertia-force for a combination of three cranks set at 120 deg. to each other, and with one crank at 90 deg. to the axis of the engine. The equation is,

$$F = \frac{WV^2}{g}\left(\frac{1.5\,R^2}{A^3_1} - \frac{0.5}{A_1} - \frac{1}{A_2}\right) \quad (36)$$

and, as in the previous case, F will not be equal to zero as neither A_1 nor A_2 is equal to R. Therefore, judging from the results of the foregoing two applications of expression (27) to the case of three cranks, it appears that the six-cylinder engine having pairs of cranks set at 120 deg. to each other does not operate in a state of reciprocating balance.

Next, applying expression (27) to the case of four cranks set at 90 deg. to each other, one crank being on head dead-center as in Fig. 6. For cranks Nos, 1, 2, 3 and 4, expression (27) becomes, respectively, expression (37), (38), (39), or (40).

$$\frac{1}{C^2}\left(\frac{R^2C^2}{R^2} - O\right) \quad (37)$$

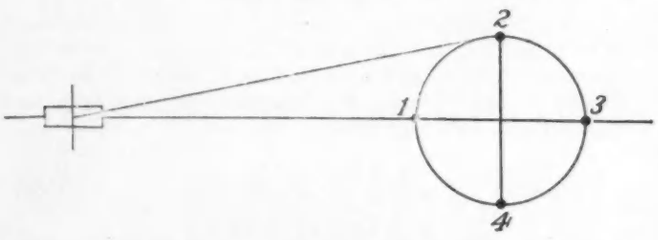


FIG. 6—FOUR-CRANK ARRANGEMENT WITH CRANKS SET AT 90 DEG. TO EACH OTHER, ONE CRANK BEING ON HEAD DEAD-CENTER

$$\frac{1}{C^2}\left(O - \frac{C^2}{A^2}\right) \quad (38)$$

$$\frac{1}{C^2}\left(\frac{R^2C^2}{R^2} - O\right) \quad (39)$$

$$\frac{1}{C^2}\left(O - \frac{C^2}{A_2}\right) \quad (40)$$

and the sum of these four values, expressions (37), (38), (39) and (40), multiplied by $WV^2 \div g$ gives the unbalanced force for a combination of four cranks set at 90 deg. to each other, the cranks occupying the positions of Fig. 6. The equation is,

$$F = \frac{WV^2}{g}\left(\frac{2}{R} - \frac{2}{A_2}\right) \quad (41)$$

and F is not equal to zero since A_2 is not equal to R.

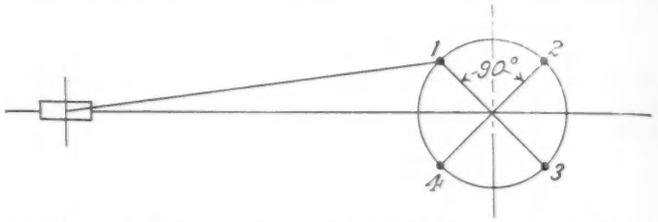


FIG. 7—FOUR-CRANK ARRANGEMENT IN WHICH ALL THE CRANKS MAKE ANGLES OF 45 DEG., PLUS OR MINUS, WITH THE AXIS OF THE ENGINE

Fig. 7 illustrates a second application of expression (27) to the four-crank arrangement, in which all the cranks make angles of 45 deg.—plus or minus—with the axis of the engine. For cranks Nos. 1, 2, 3 and 4, expression (27) becomes, respecticely, expression (42), (43), (44), or (45).

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.5\,C^2}{A^3_1} - \frac{0.5\,C^2}{A_1}\right) \quad (42)$$

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.5\,C^2}{A^3_1} - \frac{0.5\,C^2}{A_1}\right) \quad (43)$$

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.5\,C^2}{A^3_1} - \frac{0.5\,C^2}{A_1}\right) \quad (44)$$

$$\frac{1}{C^2}\left(\frac{R^2 \times 0.5\,C^2}{A^3_1} - \frac{0.5\,C^2}{A_1}\right) \quad (45)$$

and the sum of these four values, expressions (42), (43), (44) and (45), multiplied by $WV^2 \div g$ gives the unbalanced force for a combination of four cranks set at 90 deg. to each other when the cranks occupy the positions of Fig. 7. The equation is,

$$F = \frac{WV^2}{g}\left(\frac{2\,R^2}{A^3_1} - \frac{2}{A_1}\right) \quad (46)$$

and F is not zero, as A_1 is not equal to R.

The results of the foregoing applications show that the reciprocating balance of six and eight-cylinder engines is not perfect, and that nearness to exact balance will depend primarily upon the ratio of the connecting-rod to the crank. With very short rods, the unbalanced effect will be appreciable.

Comparison will now be made of six and eight-cylinder engines having equal total weight of reciprocating parts; that is, the weight of a single reciprocating-unit of the eight-cylinder engine will weigh three-quarters as much as one of the units of the six-cylinder engine.

Figs. 8 and 9 illustrate the results of a very careful calculation of the total axial-force for each 15 deg. of the crank circle, beginning at the head dead-center, for the six and the eight-cylinder engines respectively. In making the calculations equation (14) has been used, and all calculations have been carried to five or six decimal places. The data used are as follows:

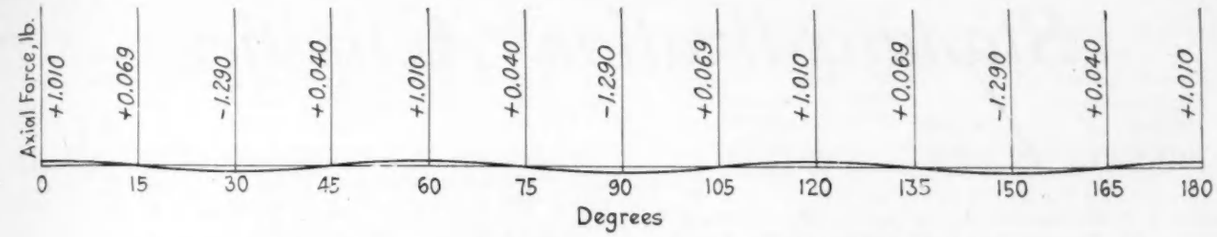


FIG. 8—AXIAL BALANCE DIAGRAM FOR A SIX-CYLINDER ENGINE
The Diagram Results from a Calculation of the Total Axial-Force for Each 15 Deg. of the Crank Circle, Beginning at Head Dead-Center.

$\frac{R}{C} = 4$, which is slightly less than in usual practice
$W_s = 6$ lb., for two piston and rod ends for the six-cylinder engine
$W_s = 4\frac{1}{2}$ lb., for two piston and rod ends for the eight-cylinder engine
$C = 3$ in., or ¼ ft.
$R = 12$ in., or 1 ft.
$N = 3000$ r.p.m.

Examination of Figs. 8 and 9 shows the decided superiority in axial balance of the six-cylinder engine over that of the eight-cylinder engine.

ANGULAR ACCELERATION OF THE CONNECTING-ROD

The angular acceleration of the connecting-rod about its mass-center results from the crankpin and wristpin reactions normal to the line of the rod, and is represented by the expression $I\alpha$, in which I is the moment of inertia of the rod about an axis through its mass-center and normal to the plane of its motion, and α is the angular acceleration of the rod. The expression for the angular acceleration of the rod is given in equation (10), which can be reduced to an expression of form similar to that of equation (26), as follows:

$$\alpha = \frac{C\omega^2 \sin\phi}{R\cos\theta} - \frac{V^2\cos^2\phi\tan\theta}{R^2\cos^2\theta} \qquad (47)$$

Referring to Fig. 1,

$$\alpha = \frac{V^2H}{C^2A} - \frac{V^2B^2H}{C^2A^3} \qquad (48)$$

$$= \frac{V^2}{C^2}\left(\frac{H}{A} - \frac{B^2H}{A^3}\right) \qquad (49)$$

$$= \frac{V^2}{C^2}H\left(\frac{A^2 - B^2}{A^3}\right) \qquad (50)$$

$$= \frac{V^2}{C^2}K\left(\frac{H}{A^3}\right) \qquad (51)$$

where $A^2 - B^2 = R^2 - C^2 = K$, as in preceding equations.

Substituting for V and C,

$$\alpha = 4\,\pi^2N^2K\left(\frac{H}{A^3}\right) \qquad (52)$$

and,

$$M = I\alpha = 4\,I\pi^2N^2K\left(\frac{H}{A^3}\right) \qquad (53)$$

Examination of equation (53) reveals the fact that this couple is zero at the dead-centers, and is a maximum when the crank is set at 90 deg. with the axis of the engine. Further study in connection with Figs. 4 and 5 shows that the compound couple for the six-cylinder engine is not zero except at points of reversal, the couple reversing every 60 deg. of shaft rotation, beginning at dead-center. This condition tends to produce an oscillation of the engine normal to its axial plane, the couple having three oscillating cycles per revolution. Examination of Figs. 6 and 7 shows that the compound couple for the eight-cylinder engine is zero for every position.

Fig. 10 illustrates the variation of the compound oscillatory couple for a six-cylinder engine having a 2⅛-in. crank and an 8¾-in. connecting-rod. The moment of inertia of the rod was determined experimentally by noting carefully its time of oscillation, and the compound oscillatory-couple was calculated carefully for maximum position and that for half way between maximum and zero, or where any crank is at 90 deg., and where any crank is 15 deg. on either side of 90 deg. The results, platted as ordinates, are in pound-feet.

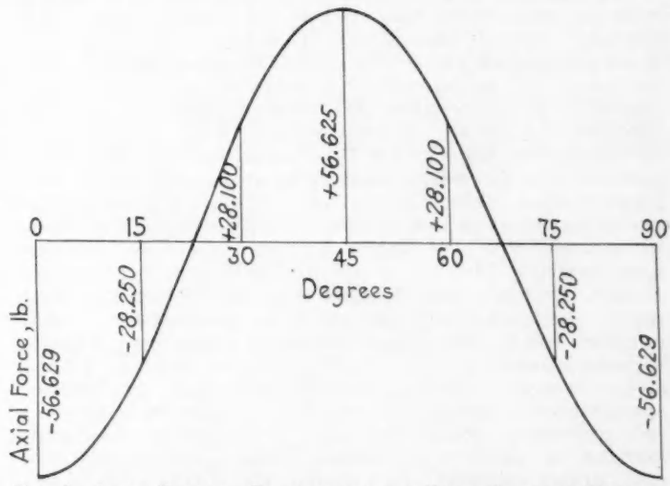


FIG. 9—AXIAL-BALANCE DIAGRAM FOR AN EIGHT-CYLINDER ENGINE
The Diagram Results from a Calculation of the Total Axial-Force for Each 15 Deg. of the Crank Circle.

To summarize the results of the foregoing analysis, it appears that the six-cylinder engine possesses superior axial balance to the eight-cylinder engine, and that the latter is superior to the six-cylinder engine from an oscillatory standpoint. A 12-cylinder in-line engine having pairs of cranks set at 60 deg. would have perfect oscillatory balance and almost perfect axial balance.

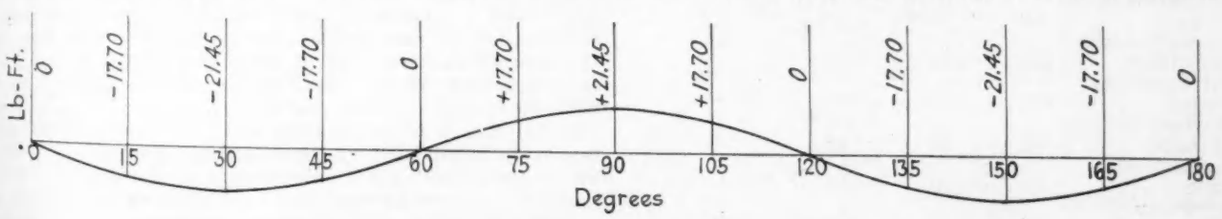


FIG. 10—OSCILLATING COUPLE OF A LIGHT SIX-CYLINDER ENGINE AT 3000 R.P.M.

Standardization Activities

SURVEYS ON S.A.E. STANDARDS

Extent of Use of Specifications To Be Determined by Periodic Questionnaire

The yardstick by which the value of standard specifications is measured is the extent to which such specifications are used. And the dependability that can be placed on standards is gaged by their uptodateness.

In an endeavor to keep the S.A.E. Specifications in line with current practice, it has been the custom to conduct surveys among manufacturers and users to whose products the various specifications apply. Such surveys may be divided into two classes: (*a*) those conducted to determine to what extent present specifications are used and to obtain suggestions for their improvement or revision, and (*b*) those conducted to determine the reception that would be accorded standardization of a new subject and to elicit information of value in formulating such a standard.

The intention originally was to survey S.A.E. Standards without regard to the date of their last revision, merely progressing through the S.A.E. HANDBOOK and covering a given number of subjects per month. Questionnaires have been sent out to date on 17 existing specifications. Summaries of replies received have been completed on 10 of the subjects. Of the 10 completed subjects, 2 have been considered and acted upon by the Division interested. The standards on these subjects, connecting-rod bolts and engine rear-support arms, were found to have such a sufficiently large percentage of users that revision of them was not demanded, in the opinion of the Engine Division. The eight subjects now awaiting Division action are as follows: carbureter flanges, flywheels and flywheel housings, flywheel-housing limits, gearshift-lever positions, felt specifications, engine numbers, lamp lenses, and tire-pump mountings. Surveys were undertaken on some of these subjects in view of criticisms received regarding various features of the present specifications, while other surveys were instituted in the routine procedure. Replies are still to be received and summarized on motor-truck bodies, plate glass, motor-truck cabs, rubber bushings, cable conduit and tubing clips, starting-motor cable, and driving-clutch drums.

TABLE 1—RESULTS OF QUESTIONNAIRES ON 10 SUBJECTS

Subject	Companies Addressed	Replies Received	Companies Using S.A.E. Specifications in Whole or in Part	Companies Having No Occasion to Use Them
Completed and Action Taken				
Connecting-Rod Bolts	81	72	56	
Engine Rear-Support Arms	86	74	45	
Completed, No Action Taken				
Carbureter Flanges	88	79	69	
Flywheels and Flywheel Housings	88	78	63	
Gearshift-Lever Positions	152	110	93	
Felt Specifications	173	61	37	
Flywheel-Housing Limits	46	46	24	2
Engine Numbers	89	80	25	
Tire-Pump Mountings	80	68	23	33

It has been found, as a result of these investigations, that many companies, while not using the standards in their entirety, follow some portion of them or base their individual designs on general features of the standards. In the majority of instances the percentage of replies has been gratifying, despite the fact that some companies have received an almost constant succession of letters and questionnaires requesting information.

Surveys have become indispensable as a means of securing information for use by a Division or Subdivision having a subject under consideration for standardization. Data are being collected by this method at present on the following subjects, most of which are in the hands of Subdivisions: airplane storage-batteries, motor-truck snowplows, duplex-carbureter flanges, engine distillate, power brakes, passenger-car-bumper spring-horn mountings, windshield-cleaner mountings, body-parts nomenclature, window-glass channels, round unslotted-head bolts, additional engine-testing forms for large airplane engines, generator couplings, and tire and rim sizes.

COMPREHENSIVE INDICES MAINTAINED

To facilitate this work it is planned to maintain in the Standards Department of the Society an index of each S.A.E. Standard and Recommended Practice, containing complete information; that is, date of original approval dates of revision, lists of personnel of Subdivisions formulating such specifications, and a progress record of surveys. The index cards will also give statistics as to the number of companies approached, the replies received, the number using the standards completely or partially, and the action taken in consequence of information obtained. It is further proposed to have each Division of the Standards Committee determine, at the time a specification is approved or revised, the period to elapse before a survey shall be made and the subject brought up for reconsideration.

It is felt that the psychological effect of having recent revision dates appear makes it worthwhile, when a Division deems it unnecessary to make any changes in a specification, to mark the specification reapproved as of the date the matter was considered. This system will, moreover, prevent any subject from being omitted from consideration, and will, undoubtedly, keep the S.A.E. HANDBOOK revised to meet the requirements of the various fields in which it should be of value to the industry.

Table 1 indicates the support that has been given to this work in connection with the 10 completed subjects investigated for revision.

The Standards Department will appreciate any constructive criticisms or comments that will facilitate this work.

PROPOSED BATTERY-TERMINALS

Specifications for Two Types To Replace Present Numerous Designs and Sizes

Very few small parts have been produced in such a profusion of sizes and designs as have storage-battery clamp-terminals. Manufacturers of these clamps complained that each new order incorporated some minor change requiring the construction of new molds. Great difficulty has also been experienced by users due to bad foundry-practice and low-copper-content alloys, resulting in considerable breakage with consequent burning out of generators in many cases. For the purpose of formulating a suitable standard terminal-design, a Subdivision of the Electrical Equipment Division was organized, with R. J. Nightingale, of the Willard Storage Battery Co., as chairman, and the following additional personnel: G. L. Kyle, USL Battery Corporation; L. E. Lighton,

Electric Storage Battery Co.; D. M. Pierson, Dodge Bros.; and a representative of the Ohio Parts Co.

At a meeting held on July 18, 1927, in Cleveland, it was decided to recommend for adoption two classes of terminal, the cable type and the strap type, each to be provided in positive and negative-terminal sizes, as shown in Table 1 and the accompanying drawings. After considerable discussion, it was decided to recommend 15/16 in. as the best all-round length, in spite of present considerable use of a slightly larger terminal, as it was felt that greater length is unnecessary, from both electrical and mechanical viewpoints, and merely adds weight and consequent cost to the terminal. The clamp, as cast, will be open slightly farther than as in present practice, to provide easier insertion on battery posts. The section through which the clamp-bolt passes is not cut away as heretofore and the proposed terminal therefore gives better protection to the bolt with less bolt area exposed to corrosion.

The clamp wall-thickness of both positive and negative terminals will be the same, contrary to the practice of many manufacturers who use the same molds, merely changing cores for the different-size post-holes.

It was further decided that standard specifications, to be of value, should include a suitable test to determine the tensile-strength of the alloy used and at the same time indicate good or bad amalgamation of the components of the alloy or any bad foundry-practice.

The following test, which has been used successfully, has been suggested for consideration:

> Terminals to be selected at random from shipments and tested for tensile-strength and elongation in the Olsen dead-weight tensile-testing machine. The terminals to be gripped by hooks fitting in the eyes of the terminal and pulled with a uniform rate of speed of 0.4 in. per min. Pulling is to be continued until the terminal breaks or is completely straightened out. In case of breakage, the maximum load is recorded. In case the terminal is straightened out without breaking, a load of 1000 lb., the maximum of the testing machine, is assumed as the figure for the tensile-strength. The percentage of elongation is also to be noted. Eighty per cent of the samples tested should show a tensile-strength of 300 lb. per sq. in., or more. In case of breakage under this load of more than 20 per cent of the samples chosen, a second lot of samples should be checked. Similar failure in the second lot is cause for rejection. [The number of samples to be taken from any given shipment has not been determined.]

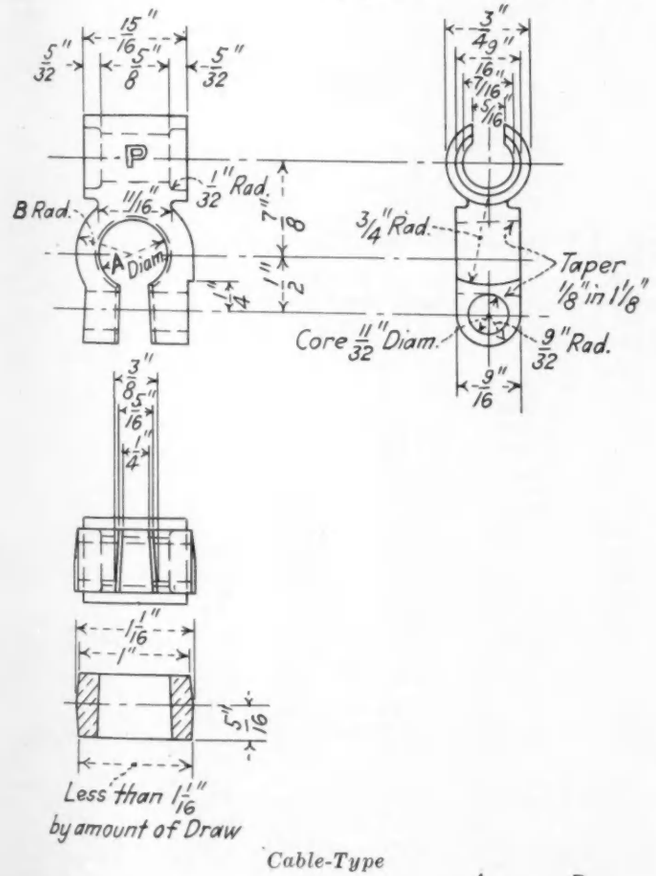
It is the consensus of opinion of the Subdivision that the standard should be extended to include the alloy from which the terminals should be cast, but, in view of the time required to make a study of this matter from a cost standpoint, no definite decision on it has been reached, although it is anticipated that S.A.E. Brass No. 44, which fills the requirements electrically and mechanically, will be specified.

Comments and criticisms of this proposed specification are invited.

SMALL-RIVET REPORT APPROVED

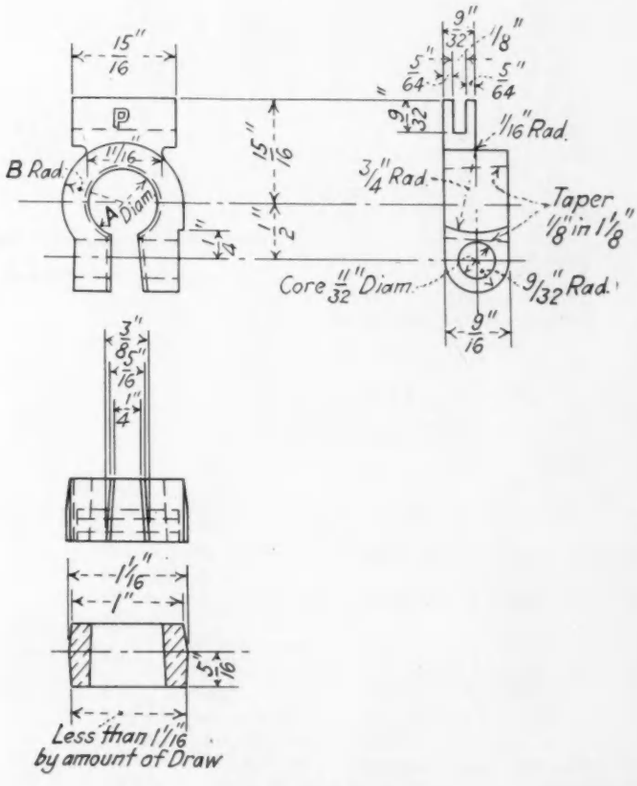
At the last Annual Meeting of the Society the report of the Sectional Committee on Bolt, Nut and Rivet Proportions that is sponsored jointly by the Society and the American

TABLE 1—SPECIFICATIONS OF PROPOSED BATTERY-TERMINALS



Cable-Type

	A Diameter	*B* Radius
Positive	11/16	17/32
Negative	5/8	1/2



Strap-Type

	A Diameter	*B* Radius
Positive	11/16	17/32
Negative	5/8	1/2

Society of Mechanical Engineers, was approved and has been confirmed subsequently by letter-ballot by the members of the Society. This report was printed on p. 21 of the January, 1927, issue of THE JOURNAL. Following approval of the report by the sponsors, it was submitted to and considered by the American Engineering Standards Committee, which, at its meeting on July 21, reported its final unanimous approval by letter-ballot. The report has since been published in pamphlet form and can be obtained at a nominal price from the office of the Society or from the American Society of Mechanical Engineers. It includes the dimensions of flat-head rivets, countersunk rivets, button-head rivets, pan-head rivets, and truss or wagon-box-head rivets 7/16 in. in diameter and smaller.

TEN-SPLINE SIDE-BEARING FITTINGS

Additional Specifications To Be Submitted to the Industry for Consideration

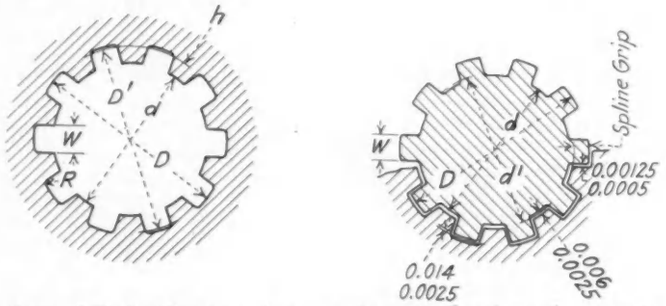
Some time ago the desirability of having a standard for a 10-spline fitting with side bearing only was suggested by several members who pointed out that, with the increased usage of splines, a number of manufacturers are using such fittings with side bearings only because of the rapid wear of the broaches.

As a result of discussion of this subject in the Transmission Division, a questionnaire was addressed to transmission, differential and rear-axle manufacturers and other users of splines to secure information regarding their practice and as to whether 10-spline practice providing for fitting on the sides only should be adopted. The replies indicated considerable interest in the subject and a Subdivision was organized to present recommendations. As a result of its study, the specifications in Tables 1, 2 and 3 have been proposed and are submitted herewith for the consideration of all interested.

The present specifications on spline fittings do not include shaft dimensions such as are shown in the accompanying tables. Suggestions are requested regarding the extent to which such dimensions will be of value if approved and whether similar dimensions should be determined for the various fittings covered by existing standards. Advice is also sought on the need for specifications for side-bearing fittings on 4, 6 and 16-spline fittings, to complete the present standards. This proposal will be presented to the Transmission Division for consideration at its first meeting during the coming season.

BRAKE SAFETY-CODE ISSUED

A report that is believed to be of considerable value to motor-vehicle manufacturers and State motor-vehicle administrators has been issued by the Bureau of Standards in the City of Washington, following final approval of the report by the American Engineering Standards Committee. The Sectional Committee that formulated the report was sponsored by the Bureau of Standards and the American Automobile Association under the American Engineering Standards Committee procedure. The report relates in gen-



NOTE: d To Be Maximum Diameter Consistent with Design of Hob. Shape Below d' To Approximate a Portion of an Ellipse
d' = Diameter to Parallel Sides

TABLE 1—SIDE-BEARING 10-SPLINE FITTING, PERMANENT FIT

Nominal Diameter	R Maximum	Broached Hole D'	Broached Hole D	Broached Hole d	Broached Hole W	Broached Hole h	Shaft D	Shaft d'	Shaft W	Shaft Spline Grip
¾	0.010	0.775	0.795	0.684	0.117	0.0465	0.753	0.677	0.1175	0.0355
		0.758	0.778	0.682	0.116	0.0370	0.747	0.672	0.1170	0.0315
⅞	0.010	0.900	0.920	0.797	0.137	0.0525	0.878	0.790	0.1375	0.0415
		0.883	0.903	0.795	0.136	0.0430	0.872	0.785	0.1370	0.0375
1	0.020	1.025	1.065	0.911	0.156	0.0580	1.003	0.904	0.1565	0.0470
		1.008	1.048	0.909	0.155	0.0485	0.997	0.899	0.1560	0.0430
1⅛	0.020	1.150	1.190	1.025	0.176	0.0635	1.128	1.018	0.1765	0.0525
		1.133	1.173	1.023	0.175	0.0540	1.122	1.013	0.1760	0.0485
1¼	0.020	1.275	1.315	1.139	0.195	0.0690	1.253	1.132	0.1955	0.0580
		1.258	1.298	1.137	0.194	0.0595	1.247	1.127	0.1950	0.0540
1⅜	0.020	1.400	1.440	1.252	0.215	0.0750	1.378	1.245	0.2155	0.0640
		1.383	1.423	1.250	0.214	0.0655	1.372	1.240	0.2150	0.0600
1½	0.030	1.525	1.585	1.366	0.234	0.0805	1.503	1.359	0.2345	0.0695
		1.508	1.568	1.364	0.233	0.0710	1.497	1.354	0.2340	0.0655
1⅝	0.030	1.650	1.710	1.480	0.254	0.0860	1.628	1.473	0.2545	0.0750
		1.633	1.693	1.478	0.253	0.0765	1.622	1.468	0.2540	0.0710
1¾	0.030	1.775	1.835	1.594	0.273	0.0915	1.753	1.587	0.2735	0.0805
		1.758	1.818	1.592	0.272	0.0820	1.747	1.582	0.2730	0.0765
2	0.040	2.025	2.105	1.820	0.312	0.1035	2.003	1.813	0.3125	0.0925
		2.008	2.088	1.818	0.311	0.0940	1.997	1.808	0.3120	0.0885
2¼	0.040	2.275	2.355	2.048	0.351	0.1145	2.253	2.041	0.3515	0.1035
		2.258	2.338	2.046	0.350	0.1050	2.247	2.036	0.3510	0.0995
2½	0.040	2.525	2.605	2.275	0.390	0.1260	2.503	2.268	0.3905	0.1150
		2.508	2.588	2.273	0.389	0.1165	2.497	2.263	0.3900	0.1110
3	0.040	3.025	3.105	2.730	0.468	0.1485	3.003	2.723	0.4685	0.1375
		3.008	3.088	2.728	0.467	0.1390	2.997	2.718	0.4680	0.1335
Tolerance		0.017	0.017	0.002	0.001	0.0095	0.006	0.005	0.0005	0.0040

TABLE 2—SIDE-BEARING 10-SPLINE FITTING, TO SLIDE WHEN NOT UNDER LOAD

Nominal Diameter	R Maximum	Broached Hole					Shaft			
		D'	D	d	W	h	D	d'	W	Spline Grip
¾	0.010	0.775	0.795	0.646	0.117	0.0655	0.753	0.639	0.1160	0.0545
		0.758	0.778	0.644	0.116	0.0560	0.747	0.634	0.1155	0.0505
⅞	0.010	0.900	0.920	0.754	0.137	0.0740	0.878	0.747	0.1360	0.0630
		0.883	0.903	0.752	0.136	0.0645	0.872	0.742	0.1355	0.0590
1	0.020	1.025	1.065	0.861	0.156	0.0830	1.003	0.854	0.1550	0.0720
		1.008	1.048	0.859	0.155	0.0735	0.997	0.849	0.1545	0.0680
1⅛	0.020	1.150	1.190	0.969	0.176	0.0915	1.128	0.962	0.1750	0.0805
		1.133	1.173	0.967	0.175	0.0820	1.122	0.957	0.1745	0.0765
1¼	0.020	1.275	1.315	1.076	0.195	0.1005	1.253	1.069	0.1940	0.0895
		1.258	1.298	1.074	0.194	0.0910	1.247	1.064	0.1935	0.0855
1⅜	0.020	1.400	1.440	1.184	0.215	0.1090	1.378	1.177	0.2140	0.0980
		1.383	1.423	1.182	0.214	0.0995	1.372	1.172	0.2135	0.0940
1½	0.030	1.525	1.585	1.291	0.234	0.1180	1.503	1.284	0.2330	0.1070
		1.508	1.568	1.289	0.233	0.1085	1.497	1.279	0.2325	0.1030
1⅝	0.030	1.650	1.710	1.399	0.254	0.1265	1.628	1.392	0.2530	0.1155
		1.633	1.693	1.397	0.253	0.1170	1.622	1.387	0.2525	0.1115
1¾	0.030	1.775	1.835	1.506	0.273	0.1355	1.753	1.499	0.2720	0.1245
		1.758	1.818	1.504	0.272	0.1260	1.747	1.494	0.2715	0.1205
2	0.040	2.025	2.105	1.720	0.312	0.1535	2.003	1.713	0.3110	0.1425
		2.008	2.088	1.718	0.311	0.1440	1.997	1.708	0.3105	0.1385
2¼	0.040	2.275	2.355	1.935	0.351	0.1710	2.253	1.928	0.3500	0.1600
		2.258	2.338	1.933	0.350	0.1615	2.247	1.923	0.3495	0.1560
2½	0.040	2.525	2.605	2.150	0.390	0.1885	2.503	2.143	0.3890	0.1775
		2.508	2.588	2.148	0.389	0.1790	2.497	2.138	0.3885	0.1735
3	0.040	3.025	3.105	2.580	0.468	0.2235	3.003	2.573	0.4670	0.2125
		3.008	3.088	2.578	0.467	0.2140	2.997	2.568	0.4665	0.2085
Tolerance		0.017	0.017	0.002	0.001	0.0095	0.006	0.005	0.0005	0.0040

TABLE 3—SIDE-BEARING 10-SPLINE FITTING, TO SLIDE WHEN UNDER LOAD

Nominal Diameter	R Maximum	Broached Hole					Shaft			
		D'	D	d	W	h	D	d'	W	Spline Grip
¾	0.010	0.775	0.795	0.609	0.117	0.0840	0.753	0.602	0.1150	0.0730
		0.758	0.778	0.607	0.116	0.0745	0.747	0.597	0.1145	0.0690
⅞	0.010	0.900	0.920	0.710	0.137	0.0960	0.878	0.703	0.1350	0.0850
		0.883	0.903	0.708	0.136	0.0865	0.872	0.698	0.1345	0.0810
1	0.020	1.025	1.065	0.811	0.156	0.1080	1.003	0.804	0.1540	0.0970
		1.008	1.048	0.809	0.155	0.0985	0.997	0.799	0.1535	0.0930
1⅛	0.020	1.150	1.190	0.912	0.176	0.1200	1.128	0.905	0.1740	0.1090
		1.133	1.173	0.910	0.175	0.1105	1.122	0.900	0.1735	0.1050
1¼	0.020	1.275	1.315	1.014	0.195	0.1315	1.253	1.007	0.1930	0.1205
		1.258	1.298	1.012	0.194	0.1220	1.247	1.002	0.1925	0.1165
1⅜	0.020	1.400	1.440	1.115	0.215	0.1435	1.378	1.108	0.2130	0.1325
		1.383	1.423	1.113	0.214	0.1340	1.372	1.103	0.2125	0.1285
1½	0.030	1.525	1.585	1.216	0.234	0.1555	1.503	1.209	0.2320	0.1445
		1.508	1.568	1.214	0.233	0.1460	1.497	1.204	0.2315	0.1405
1⅝	0.030	1.650	1.710	1.317	0.254	0.1675	1.628	1.310	0.2520	0.1565
		1.633	1.693	1.315	0.253	0.1580	1.622	1.305	0.2515	0.1525
1¾	0.030	1.775	1.835	1.419	0.273	0.1790	1.753	1.412	0.2710	0.1680
		1.758	1.818	1.417	0.272	0.1695	1.747	1.407	0.2705	0.1640
2	0.040	2.025	2.105	1.620	0.312	0.2035	2.003	1.613	0.3100	0.1925
		2.008	2.088	1.618	0.311	0.1940	1.997	1.608	0.3095	0.1885
2¼	0.040	2.275	2.355	1.823	0.351	0.2270	2.253	1.816	0.3490	0.2160
		2.258	2.338	1.821	0.350	0.2175	2.247	1.811	0.3485	0.2120
2½	0.040	2.525	2.605	2.025	0.390	0.2510	2.503	2.018	0.3880	0.2400
		2.508	2.588	2.023	0.389	0.2415	2.497	2.013	0.3875	0.2360
3	0.040	3.025	3.105	2.430	0.468	0.2985	3.003	2.423	0.4660	0.2875
		3.008	3.088	2.428	0.467	0.2890	2.997	2.418	0.4655	0.2835
Tolerance		0.017	0.017	0.002	0.001	0.0095	0.006	0.005	0.0005	0.0040

eral to the minimum acceptable retardation for various types of motor-vehicle under the action of brakes and to methods of making service tests of brakes. The code was reviewed on p. 681 of the May, 1927, issue of THE JOURNAL.

REVISED S.A.E. HANDBOOK OUT SEPT. 15

New Page-Numbering System and Thumb Indexing Are Features of This Issue

The September, 1927, issue of the S.A.E. HANDBOOK will be off the press Sept. 15 and will be mailed to members on or about that date.

This is the fourth bound volume to be published, and with this issue the page-numbering system, used with the loose-leaf system and held over in the first three bound volumes, has been discarded. Pages of the current issue will be numbered consecutively, to facilitate the locating of specifications from the index.

The locations of the general index section, containing the Standards Committee personnel and other general information, and the section containing the list of Manufacturers and Advertisers, are marked by two thumb-indices. Considerable difficulty has been experienced in the past in locating the general index in the book and it is felt that this new feature will add much to the ease with which the S.A.E. HANDBOOK can be used.

The revisions, cancellations and new specifications which were the subject of action by the Standards Committee at the Summer Meeting and were printed in the May, 1927, issue

of THE JOURNAL, comprised 7 new specifications, 12 revisions and 2 cancellations, on the following subjects:

Subject	Change
Instrument Mountings	Revised
Automobile Wiring	Revised
Distributor Nipples	New
Body-Lighting Switches	New
Electrical-Instrument Binding-Posts	New
Dome-Light Lamp-Sockets	New
Roller Bearings	Revised
Passenger-Car Bumpers	Revised
Oilless Bushings	Cancelled
Split and Tubular Rivets	New
S.A.E. Steel 1046	Cancelled
S.A.E. Steel 2512	Revised
S.A.E. Steel 4615	Revised
S.A.E. Steel 3415	Revised
S.A.E. Steel 3435	Revised
S.A.E. Steel 3450	Revised
Heat-Treatment Definitions	New
Flexible Discs	Revised
Ignition Nomenclature	Revised
Electrical-Instrument Nomenclature	Revised
Turning-Radius	New

The postal card, on which to suggest the names of prospective members of the Society, which was first inserted in the March issue, has been continued in the September issue, owing to the gratifying results obtained, and will be found in the back of the book. Members are urgently requested to make use of the card found in this new issue.

The S.A.E. HANDBOOK List of Manufacturers, found in the advertising section, has been brought uptodate by the inclusion of approximately 145 additional companies not appearing in the March issue, and by numerous corrections and eliminations made necessary by the New Certification Forms signed by the various manufacturers. Manufacturers will be asked to submit new Certification Forms prior to each issue, so that the information contained in this list will be correct up to the time of going to press. In the September issue it has been necessary to withdraw the names of a number of manufacturers who failed to respond to the original letter or to the follow-up letter requesting the return of the form previously sent them, the assumption being that this indicated that their products do not conform to S.A.E. Specifications.

LENS DIAMETERS AND PRISM AREAS

In view of the widespread activity on the subject of headlamps and lighting, the Lighting Division believes it advisable to investigate the subject of head-lamp lens-diameters and prism areas, with a view to revising present specifications, if need be, to meet current requirements. A questionnaire was addressed to users of lenses to determine their requirements and to obtain suggestions that will be helpful when considering this subject.

As a result of the replies, a Subdivision is being organized to study the subject thoroughly and it is anticipated that some recommendation will be made to the Lighting Division at its next meeting.

RECOVERY OF MAJOR REFINED OIL-PRODUCTS

ONE of the most important duties of the refiner is to balance output and demand; in other words, to regulate, if possible, the recoveries of the various products to meet the changing demands of the consumer. Gasoline affords the best general example of this fact. Because of the demand, the refineries of the United States in 10 years increased their recovery of gasoline from 19.8 to 35.1 per cent. At the same time the demand for kerosene for lighting purposes has fallen off, and refiners are cutting deeper into what were formerly the kerosene fractions to supply motorists with gasoline. The increased recovery of gasoline has been due primarily to greater use of natural-gas gasoline, to improvements in fractionation and to wider use of the cracking process. Changes in the specifications for gasoline, allowing heavier fractions to be used as motor fuel, have also played an important part in keeping the output of gasoline in pace with automobile registrations. Very little change has been made in the percentage recovery of gas oil and fuel oil, approximately one-half of the total crude petroleum-run to stills having been recovered as such in 1917 and 1925. Although the demand for lubricants has increased steadily in recent years, the percentage recovery has decreased.

The common methods of producing gasoline are by ordinary distillation, by cracking and through the use of natural-gas gasoline. The figures show that for the year 1925, 66.0 per cent of the total gasoline production was attributable to the straight-run process; 26.4 per cent to cracking; and the remainder, or 7.6 per cent, to natural-gas gasoline. Although no figures of earlier years are available for comparison, it is certain that there has been an increase, at the expense of straight distillation, in the proportions attributable to cracking and to natural-gas gasoline. The last-named method produces comparatively little gasoline directly and is chiefly valuable in the blending of low-grade motor-fuel to bring it up to specifications.

During the year 1925, 68,583,000 bbl. of gasoline was produced by cracking, and 19,636,000 bbl. of natural-gas gasoline was reported as blended or run to stills. There remains, by subtraction, 171,382,000 bbl., as produced by the straight-run process.

Although no official figures for 1924 are available for comparison, it is probable that gasoline from cracking did not comprise more than one-fifth of the total production, as compared to more than one-fourth in 1925. It seems likely that official figures will show that at the end of 1926 one-third of the total output of gasoline was produced by cracking.

The capacity of a cracking plant cannot be accurately measured, as this depends on the method of its operation. For example, some refineries find it more economical to extract as much gasoline as possible from their cracking stocks, or, in other words, to recycle their charging stock; other refineries do not recycle. Obviously, the charging capacity of the latter plants is greater than that of the former.

NUMBER OF CRACKING PLANTS

On June 1, 1926, 2559 cracking units were completed or being built in the United States; they had a total charging capacity of 940,090 bbl., from which a total potential recovery of gasoline amounting to 302,147 bbl., or 32.1 per cent of the charging stock, could be obtained. This represents an increase in total capacity over 1925 of 13 per cent. Of the total units for 1926, 2337 units, with a total capacity of 844,800 bbl., and a gasoline recovery of 270,503 bbl., were reported as operating. As the production of gasoline by cracking on June 1, 1926, was at the rate of 241,000 bbl. per day, it is obvious that the cracking plants at that time were running at 89 per cent of their capacity.

Texas, with a total daily capacity of more than 200,000 bbl. of charging stock, is the leading State and district. The major part of the cracking capacity of the State is centered on the Gulf Coast, where some of the largest refineries in the Country are situated. The Atlantic Coast and the Indiana-Illinois distict are also great centers of cracking. California at present has a comparatively small cracking-capacity but, through experimental work and construction now under way, is safeguarding itself against the day when its production of crude oil will not be so great.—From Bureau of Mines Bulletin No. 280.

MASS TRANSPORTATION IN CITIES

WE are trying to run "express, local and freight" services on surface streets already cluttered by business. A modern transit-system handles 20 per cent of the total traffic in the maximum-rush hour, and at least the entire population once every day. Rapid-transit-system peak-loads run from 4 to 10 times mid-day movement. In large cities, rush-hour "tripper-cars" can make only one load-trip during each rush period. While central "loop-traffic" will always be heaviest, cities are developing more and more through-riding and crosstown riding, entirely outside of the loop.

Transit routing and terminals are thus of fundamental importance, though many systems still adhere, mainly by necessity, to the "town-pump" system of focusing all service and transfer facilities at the center, which involves the serious question of franchises. Chicago has so decentralized with outside crosstown lines that, with over 3,000,000 people and 300 sq. miles of area, surface lines still handle the major portion of passenger traffic, despite the elevated system, express and local.

After years of study of transit and traffic and the practical aspects of city planning, zoning and motor transport, I submit the proposition that the electric car, mainly surface-transit, is still the essential backbone of passenger mass-transportation. The volume of movement is too great for small units.

Must Segregate Fast from Slow Traffic

Many city industries are delivering to terminal by truck, rather than incur the delay of terminal interchange. The Pennsylvania Railroad has abandoned its way-freights within an 80-mile radius of Philadelphia, in favor of the motor-truck. Cincinnati interchanges freight between roads by motor-trucks. Clearly, the tendency of local freight-transport is more and more toward the public streets, a result found in the traffic analysis of any large city. In some downtown traffic, truck and delivery movement is perhaps 50 per cent of the automobile movement. Yet it has received very little, if any, detailed study and consideration.

The only way to assure needed speed-differentials is by traffic segregation in the Thoroughfare Plan with different streets so far as available for transit, which usually means business streets, for fast traffic, usually automobiles and motorcoaches, and for slow heavy-duty trucking. Some city-plans call for "heavy-traffic streets," which should refer to volume of fast traffic rather than to slow cumbersome freight-traffic. On transit trunks lined with business, speed traffic should be diverted so far as possible to through-speedways or express-streets, unless safety loading-stations are well marked upon the pavement. These are also useful as pedestrian safety-stations.

All things considered, fixed obstructions in the roadway, such as loading-stations, signal-towers, blinkers, and the like, should not be encouraged, with exceptions of course. Full street-capacity ought to be reserved for movement. Street safety-zones furnish the maximum relief with the least obstruction, and when not occupied may become part of the open thoroughfare as in Detroit. I see no justification for removing from use 27 to 30 ft. of a valuable roadway 24 hr. per day to accommodate infrequent car-schedules. Downtown is another matter. The headway or density should control.

It appears from experience that large-capacity motor-coaches, especially double-deck vehicles, cannot make the high schedule-speed demanded in mass transportation, largely due to design restrictions and unavoidably slow loading and unloading. The small-capacity unit really fulfills a good purpose on a transit trunk. The real reason seven-passenger jitneys have survived in Detroit is that they are needed. Making only two or three stops per mile, they are able to double the street-car speed and far exceed the local motor-coaches. Large-capacity motorcoaches of course have their field, especially in developing new routes, distinctly not on transit trunks.

Financing traffic street-pavement at $50,000 or more per mile is a far larger problem than financing railway track at $65,000 per mile, exclusive of pavement. It will not do to wave the matter aside as one of general taxation; and the cost of motor "tracks" will soon have to be recognized as part of the cost of transportation by rubber, as well as by rail. This economic necessity points the warning finger to the absolute need for segregation in the Thoroughfare Plan and proper streets designed to suit that segregation.

Must Develop Cheap Day Storage

Railroads cannot operate without terminals. But we are expecting this from traffic. I refer to day storage as distinct from short-time parking. This problem has been utterly neglected. A few deluxe garages charging 75 cents to $1 per day will have no appreciable effect upon congestion. Day storage for not more than 25 cents will have to be developed if real results are to be expected. Garaging has thus become a major national utility, and the community itself may have to undertake at cost some form of self-supporting garage service. In any event, it should be distributed in small units rather than concentrated in large ones, for ramp or elevator capacity yielding the necessary speed and safety of exit-entrance for rush-hour peak runs into prohibitive investments and rates. Rear-lot areas, not high-priced frontages, must be used for this purpose, or rear lots with arcade front-entrance.

The efficient method of arcading to widen roadways to double present capacity, while still preserving the old air-rights, has made no progress because of building-owners' opposition, to secure the last inch of ground frontage. Yet, wholesale arcading would probably cost not over 25 per cent of full street-widening. The Commonwealth Building, Philadelphia, and the Vesey Street Telephone Building, New York City, are good examples. Woodward Avenue, Detroit, scheduled for widening, has now reached frontage values of from $800 to $6,000 tax value per unit front-foot, averaging over $2,000 market value. To widen each side 20 ft. at this price would cost over $4,000,000 per mile, without damages or pavement.

The alternative is double-decking, even more financially strenuous. The South Water Street double-deck improvemnt along the Chicago River, known as Wacker Way, cost $30,000,000 per mile, the same as the London widening, Kings Highway to the Strand. Although, in Chicago the benefit assessment practically absorbed the damages awarded. It is clear that few cities can undertake such an ambitious program over large areas, with the additional complication of ascending ramp and the problem of ventilation of the lower level.

Full Capacity of Streets Not Utilized

A railroad superintendent operating on two tracks of a four or six-track system would be fired. Yet we are doing just that thing in traffic. Until we devise some equitable source of further public revenue for vast public improvements, higher efficiency in mass-transportation, rail and rubber, is our main avenue of escape. In one larger city with 90-ft. streets and 60-ft. pavement, I found within the mile square only 25 per cent traffic-efficiency, assuming solid parking, or perhaps 12 per cent clear. This city was actually encouraging one-line traffic each way and could easily have doubled its capacity. I think we must come to parallel lanes marked with white paving-blocks, or flat white-metal plates. The capacity of our streets now is reduced at least 50 per cent by "meandering," or straddling lanes. Big motorcoaches are notorious offenders in this respect.

The shortest possible signal-interval is essential for maxi-

mum volumetric efficiency. This can be determined only by "calibrating" a traffic crossing under different load-conditions. In general, signal installations have retarded transit and traffic movement throughout the Country and diverted traffic from the logical arteries. One of our largest cities installed a stop-and-run system, 100-sec. cycle, on its main business-trunk carrying rush-hour car service at 22-sec. headway. The result, which any transportation man could foretell, was from 2 to 3 min. added trip-time to every car entering the business district. It is not enough to hide behind the slogan "order and safety." We must have both safety and speed. But this will never be realized until mass-transportation, both rail and rubber, is designed and operated collectively along modern transportation lines, and so conceived in the city plan.—J. Rowland Bibbins, before Chicago City-Traffic Conference.

AUTOMOTIVE RESEARCH

(*Concluded from p.* 224)

cubic feet per minute. The small test-meter displaces 1 cu. ft. of air for every 15 revolutions of the electric motor.

Method of Operation

The total number of meter revolutions per test is read on a Veeder counter driven from the rotor shaft through a positive electromagnetic clutch. The magnet is energized simultaneously with the starting of the dynamometer revolution-counter and of the stop-watch at the beginning of the test. Both the driving and the driven faces of the clutch are serrated to prevent slippage when the clutch is engaged and to release instantly when the test is completed. Readings are always taken from a stationary counter.

The rotary-displacement meter has been carefully checked against a new bellows-type air-meter at flow rates varying from 18 to 175 cu. ft. per min. The difference between the two meters was less than 1 per cent over the entire range.

A general conception of the meter can be obtained from Fig. 2, which shows its application to a test engine. Mounting the control board on the frame with the meter would improve its appearance and its maneuverability, but the accuracy and the ease of manipulation leave little to be desired.—H. A. Huebotter.

MEASURING GRADES CARS CAN CLIMB

Computations of Hill-Climbing Ability Based on Data Easily Obtainable

The hill-climbing ability of a car can be measured by observing the steepest grade on which a uniform speed can be maintained. The grade will vary with the car speed, and for average passenger-cars in high gear will reach a maximum value of from 8 to 12 per cent at speeds near 20 m.p.h. Unfortunately, hill-climbing ability rarely can be measured in this way because of the difficulty of finding a hill of the proper grade. The hill is sometimes too steep, causing a loss of speed, and sometimes not steep enough, causing gain of speed. By test on hills of known grades, limits between which the true hill-climbing ability of the car lies can be determined.

A truer measure of hill-climbing ability can be had by computation based on data obtained while climbing any hill of known slope. This method depends on finding a grade correction from the observed rate of change of speed, to be added to the grade of the hill if the speed was increasing, or subtracted from the grade if the speed was decreasing. The required data are the time by stop-watch for speed change between 15 and 20 m.p.h., or thereabouts. The grade correction is computed by converting the change in speed from miles per hour into feet per second, dividing the result by the time in seconds and by the acceleration of gravity, 32.2, and multiplying by 100. The result will be in per cent, which can be added to or subtracted from the grade as explained.

Examples Illustrate Method of Computation

To illustrate the method more fully, an example will be given of observations made by me.

Case 1—The car was run up a 12-per cent grade, losing speed from 21 to 14 m.p.h. in 18.8 sec. The grade correction was made by changing the loss of speed from 7 m.p.h. into its equivalent 10.3 ft. per sec., dividing the latter successively by 18.8 and 32.2, and multiplying by 100, giving as a result 1.7 per cent. The true grade the car can climb is then found by computation as 12.0 minus 1.7, or 10.3 per cent.

Case 2—The car was run up a 9.8-per cent grade, gaining speed from 15 to 18 m.p.h. in 25.3 sec. The grade correction was made by changing the gain of speed from 3 m.p.h. into 4.4 ft. per sec., dividing successively by 25.3 and 32.2, and multiplying by 100, giving as a result 0.54 per cent. The true grade the car can climb is then found by computation as 9.80 plus 0.54, or 10.34 per cent.

In theory, identical results should be obtained from any two experiments of this kind, and this is nearly verified in the above examples. In practice, observational errors will occur in measuring the time, in inaccuracies in the tachometer, and in other ways, which will prevent perfect consistency in the results. Making all allowances, however, the method appears to give some practical aid in making tests of hill-climbing ability of cars.

Measurement by Chassis Dynamometer

Another way of measuring hill-climbing ability is by the use of a laboratory chassis-dynamometer. This method avoids all uncertainty as to the slope of the road. The pulling power of the engine is actually measured in pounds at the tire circumference. A laboratory test of this kind was made just previously to the road tests mentioned. The rear-wheel tractive force at 17 m.p.h. was 402 lb. Deducting the front-wheel rolling-resistance of 24 lb. and the computed wind-resistance of 15 lb., the net pull available for grade was 363 lb. Dividing the net pull by the total weight of 3680 lb. including passengers, and multiplying the result by 100, the grade is found to be 9.9 per cent.

Comparing the grade obtained by road test with that found by the laboratory method, the difference is seen to be approximately 0.4 per cent less by the laboratory method. Considering the difficulties of the problem, a better agreement perhaps could not be expected.—E. H. Lockwood.